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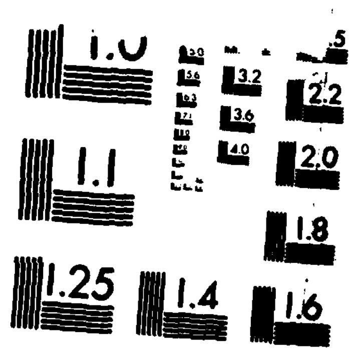

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MODELING AIRCRAFT ATTRITION
IN THE AIR DEFENSE ENVIRONMENT

by

George D. Panagakos

March 1986

Thesis Advisor: Jack B. Gafford

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Modeling Aircraft Attrition in the Air Defense Environment

by

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requirements for the degree of

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This thesis presents a high resolution, computer simulation model of aircraft attrition in the air defense enviroment. The model employs extensive pre-processing submodels and programs in order to efficiently examine tactical scenarios and reduce program execution time. The pre-processing outputs are loaded into a dynamic simulation submodel to analyze the aircraft/air defense engagement sequence. The overall simulation model is modular and can be easily modified to satisfy the user's particular analysis objectives.

TABLE OF CONTENTS

I. INTRODUCTION 12

II. TERRAIN SIMULATION 17

A. ACCURACY 17

1. Formation 19

2. Number of Aircraft 20

3. Flight Level 20

B. CALCULATION OF THE GRID SQUARE ALTITUDES . . . 20

C. ADVANTAGES AND DISADVANTAGES OF THE GRID SQUARE METHOD 27

1. Advantages 27

2. Disadvantages 27

III. CONSTRUCTION OF A MINIMUM ALTITUDE GRID 29

A. INTRODUCTION 29

B. DESCRIPTION OF THE MODEL 30

1. Calculation of Distances D1 and D2 33

2. Calculation of the Of Minimum Altitude . . 35

3. Calculation of the Maximum Altitude . . . 37

C. ADVANTAGES AND DISADVANTAGES 38

1. Advantages 38

2. Disadvantages 39

IV. LINE-OF-SIGHT AND POSSIBILITY OF DETECTION 41

A. INTRODUCTION 41

B. LINE-OF-SIGHT DETERMINATION 41

C. DETERMINING THE POSSIBILITY OF DETECTION . . . 45

D. ADVANTAGES AND DISADVANTAGES 51

1. Advantages 51

2. Disadvantages 51

V. AIRCRAFT MOVEMENT MODEL 52

A. INTRODUCTION 52

B. DESCRIPTION 52

1. Start Time for Penetrating the Enemy Area 53

2. Initial Position 54

3. Heading of the Flight Path 55

4. Distance 57

5. Speed 57

6. Altitude 58

C. ADVANTAGES AND DISADVANTAGES OF THE AIRCRAFT MOVEMENT MODEL 60

1. Advantages 60

2. Disadvantages 60

VI. TARGET DETECTION, INTERCEPTION AND PRIORITY MODELS 61

A. TARGET DETECTION MODEL 61

B. TARGET INTERCEPTION MODEL 65

C. TARGET PRIORITY MODEL 71

VII. ADDITIONAL MODELS 77

A. IDENTIFICATION FRIEND OR FOE (IFF) MODEL . . . 77

1. Introduction 77

2. Description 77

B. ELECRONIC COUNTERMEASURES(ECM) 80

1. Introduction 80
2. Description 80
C. COMMAND AND CONTROL MODEL 90
1. Introduction 90
2. Description 90
D. RADAR PERFORMANCE MODEL 92
1. Introduction 92
2. Description 92
E. PROBABILITY OF KILL MODEL 94
1. Introduction 94
2. Description 95
VIII. COMPUTER PROGRAM "AIRMODEL" 97
A. INTRODUCTION 97
B. DESCRIPTION 100
1. Main 100
2. Site 105
3. IDIF 105
4. Track 106
5. Fire 107
6. INTER 107
7. ASSESS 108
8. PKILL 109
9. RANDOM 110
IX. SIMULATION OF A PARTICULAR SCENARIO 111
A. INTRODUCTION 111
B. DESCRIPTION OF THE SCENARIO 111
1. Map 111

2. Aircraft Formations 113
3. Radar Sites 116
C. SUMMARY STEPS FOR CALCULATING THE ATTRITION RATE OF THE ATTACKING AIRCRAFT FORMATION . . . 117
1. Pre-processing Phase 117
2. Dynamic Phase. 118
D. EXECUTING AIRMODEL 119
1. Database 119
2. Result 120
3. Sensitivity Analysis 128
X. SUMMARY AND CONCLUSION 131
APPENDIX A 135
A. PURPOSE 135
B. DESCRIPTION OF THE TERRAIN SIMULATION PROGRAM 135
1. Input 135
2. Output 135
APPENDIX B 137
A. FUNCTION "MALTI" 137
B. FUNCTION "GRID" 138
APPENDIX C 142
APPENDIX D 144
A. CPM 144
B. ERROR 145
APPENDIX E 148
A. TARGET DETECTION MODEL 148
1. Detect 148

2. Error 148

B. TARGET INTERCEPTION MODEL 149

C. TARGET PRIORITY MODEL 150

APPENDIX F 156

APPENDIX G 166

LIST OF REFERENCES 196

INITIAL DISTRIBUTION 197

LIST OF TABLES

1. ALTITUDES OF THE GRID SQUARES 24

2. AVERAGE ALTITUDES OF GRID SQUARES 25

3. OUTPUT OF "MOVEMENT" PROGRAM 59

LIST OF FIGURES

2.1 Formation of Three Aircraft 18
2.2 Formation of Five Aircraft 19
2.3 Terrain Divided into Square Grids 21
2.4 Grid Squares and Contours Curves 23
2.5 Plot of Terrain 26
2.6 Terrain Represented by a Grid Square 28
3.1 Average Altitude Grid 30
3.2 Profile of Average Altitude 31
3.3 Profile of Average Altitude adjusted for Earth Curvature 32
3.4 Calculating Minimum Altitude al 33
3.5 Minimum Altitudes along the Line-of-Sight 38
3.6 Minimum Altitudes 39
4.1 Line-of-Sight Restricted by Hill 42
4.2 Line-of-Sight Restricted by Earth Curvature . . . 43
4.3 Minimum Altitudes 44
4.4 Visible Area for Target Flying at 500 Feet . . . 46
4.5 Visible Area for Target Flying at 2000 Feet . . . 47
4.6 Visible Area for Target Flying at 6000 Feet . . . 48
4.7 Calculation of the Slant Range 50
5.1 A Typical Flight Path 53
5.2 Flight Path Design 56
6.1 Radar Site-Target Flight Route Relation 63
6.2 A Detection State Matrix for One Site 64

6.3 Two Methods of Interception Geometry 66

6.4 Interception Geometry 67

6.5 An Interception State Matrix for One Site 71

6.6 Two Attacking Targets 72

6.7 Attacking and Returning Targets 73

6.8 Two Returning Targets 74

6.9 Priority State Matrix 75

7.1 Logic Diagram of ECM Model 78

7.2 Aircraft Formation Detected by Radar Site 81

7.3 Aircraft Formation Using ECM 82

7.4 Parameters of ECM Device 83

7.5 ECM Efficiency - Distance 84

7.6 Time Events Matrix 86

7.7 Breaking Aquisition Model 87

7.8 ECM Process Logic Diagram 89

7.9 Logic Diagram of Command and Control Model 91

7.10 Logic Diagram of Radar Site's Performance Model 93

7.11 Probability of Kill Model 94

8.1 The Engagement Sequence 98

8.2 Airmodel Flow Chart 99

9.1 Scenario 112

9.2 Attrition Rate of each Target 129

9.3 Total Attrition Rate 130

I. INTRODUCTION

A. BACKGROUND

In modern warfare, predicting the attrition of high performance aircraft as they penetrate the hostile area is very important. In general, this prediction depends on many variables. Factors such as weather, terrain, aircraft performance and weapons capabilities affect the air battle greatly. Calculation of aircraft attrition, in large-scale combat models, is difficult because the process is highly stochastic. Current modeling has analyzed aircraft attrition and air defense effectiveness by aggregating many factors.

Two large high resolution combat models, CORDIVEM and VECTOR-2, have used aggregate air models in an attempt to evaluate the effect of air defense against overflight aircraft. The model designers have tried to represent warfare in a realistic and accurate way. However they have ignored or oversimplified factors such as command and control, terrain masking, weather, and enemy electronic countermeasures(ECM). The command and control issues have been oversimplified by assuming that radar sites and firing units act autonomously. Terrain masking, which is extremely important for aircraft survivability, has been totally ignored. Most terrain models require many computations, large data bases, and are cumbersome. ECM capabilities have

been disregarded because they also require extremely high resolution modeling to yield reliable results. High resolution models can be used to combine these factors and add realism to the air battle.

Due to the aggregation methods, sensitivity analysis is much more difficult. The model builder can not easily estimate the change in attrition rate when critical parameters such as aircraft flight level, type of aircraft formation, aircraft speed and ECM capabilities are varied. In general, the current air models have sacrificed detail for computational simplicity.

B. THE PROBLEM

A high resolution (HIRES) model which permits realistic analysis of aircraft attrition must be very complex and contain many submodels and subprograms. Furthermore, the computer time required to execute a HIRES model, as part of a high resolution wargame, is significant. The task facing the model builder is to design a HIRES air model that is efficient and produces acceptable results in a timely manner.

Lee and Cho introduced a framework for designing attrition models in their Naval Postgraduate thesis entitled, A Generalized Approach to Air Defense Combat Modeling, September 1985. This author has implemented their concepts by designing and programming a high resolution aircraft attrition model which improves the analyst's capability to account for the uncertainties in the air attack/defense problem.

C. THESIS OBJECTIVES

The objectives of this thesis are:

1. To create a model which realistically estimates the attrition of an aircraft formation during its route across the hostile area.

2. To program the model so that most calculations are performed in an off-line, pre-processing mode.

3. To design the dynamic simulation segment of the model to take advantage of the pre-processing output and efficiently simulate the stochastic elements of the air battle.

4. To perform sensitivity analyses of the critical variables in the air attack/defense problem.

D. APPROACH

The air model will be developed in the following sequence.

1. Pre-Processing Sub-Models

The deterministic elements of the air battle will be accounted for in this phase.

a. Terrain

The terrain module will be developed and used to calculate a minimum altitude of detection matrix for all radar sites contained in the simulation (Chapters II and III).

b. Detection Geometry

The detection module will be developed and used to determine the possibility of detection based on line-of-sight and acquisition radar range considerations (Chapter IV)

c. Aircraft Movement

The aircraft movement module will be developed to simulate the flight paths of all the aircraft in the scenario (Chapter V).

d. Engagement

The detection, acquisition, interception, and priorization modules will be developed to determine the feasibility of the engagement sequence (Chapter VI)

2. Dynamic Sub-Models

The stochastic elements of the air battle will be simulated in this phase. These sub-models will allow for the replication of scenarios and the summarization of probabilistic events. The dynamic portion of the model will use the outputs of the pre-processing submodels for each replication (Chapter VII and VIII).

3. Scenario Demonstration and Model Execution

In Chapter IX, a specific scenario will be described and loaded into the air model. This scenario will be used to demonstrate the execution of the computer simulation and generate sample outputs of a typical air battle. The outputs will be statistically summarized and analyzed. Sensitivity analysis will be performed to demonstrate the relationship between aircraft altitude and expected attrition rate.

E. SUMMARY

The thesis will demonstrate that aircraft attrition in an air defense environment can be efficiently and accuratly modeled using high resolution techniques and efficient use of off-line, pre-processing programs and routines.

II. TERRAIN SIMULATION

Terrain simulation must be developed to represent the terrain over which the attacking formation flies.

The attacking aircraft a/c uses terrain masking in order to avoid enemy radar detection. Since radars require line-of-sight, earth detection can be restricted by the interfering terrain form. In order to determine if a radar has line-of-sight (LOS) to the a/c in the air defense simulation, it is necessary to analyze the terrain which lies between the radar and the a/c formation.

This terrain simulation developed in this thesis is based on a grid square method. The area to be analyzed is divided into uniform squares. Other shape such as hexagon could also be used. The length of the side of each square depends on the accuracy of the terrain representation required. The smaller the length, the greater the accuracy of the terrain model. If great accuracy is desired, extensive calculations must be anticipated. This chapter will describe the terrain model and the factors which affect the terrain simulation accuracy.

A. ACCURACY

The most important question concerning terrain modeling is determining the appropriate degree of accuracy. A high resolution terrain representation will require extensive computer processing. Furthermore the formation of the

attacking a/c, the number of a/c, and the flight altitude are also factors which affect the accuracy question and must be considered.

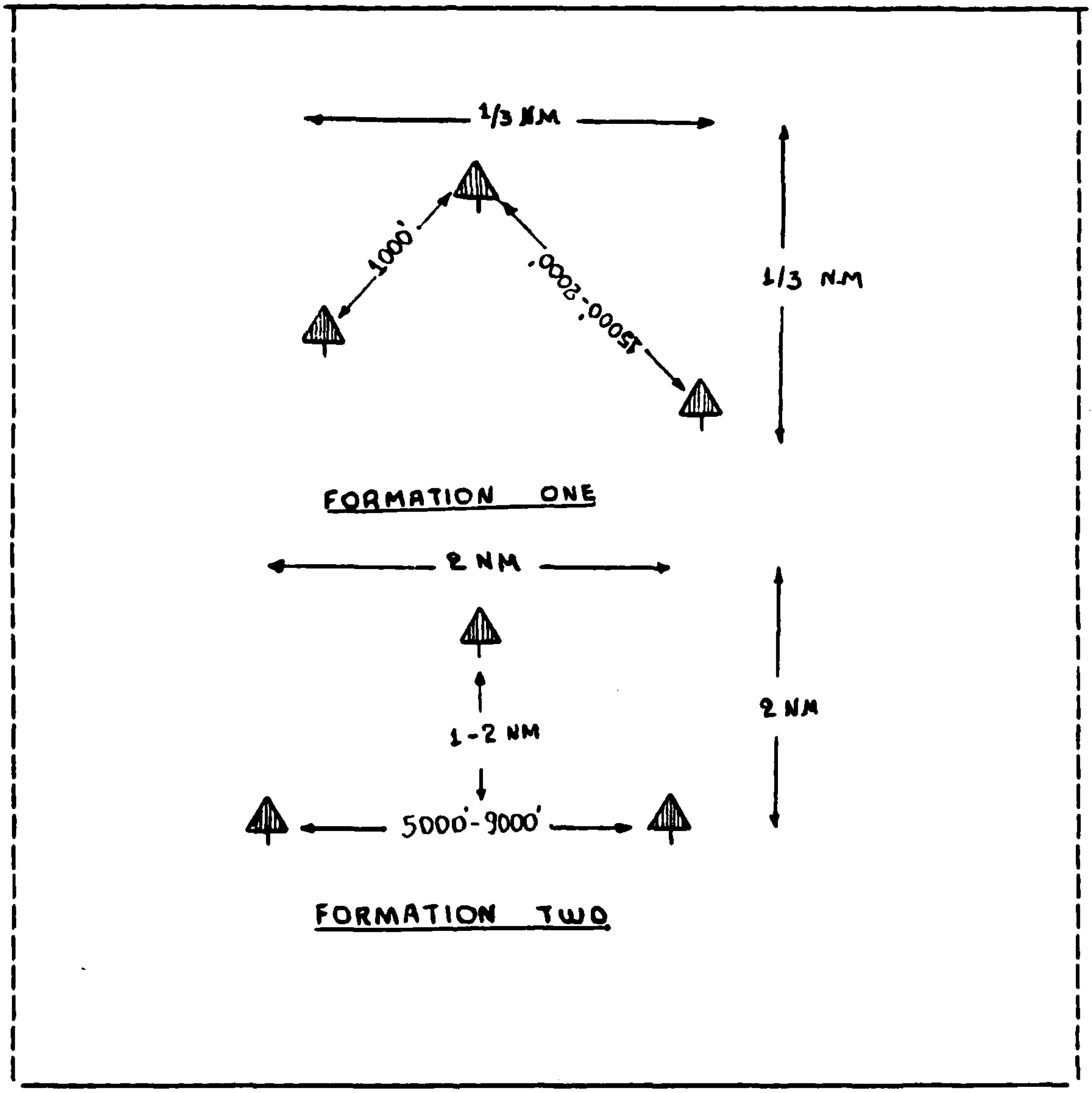

Figure 2.1 Formation of Three A/C

1. <u>Formation</u>

Attack formations vary greatly and depend on the tactics and the mission. For example, consider the two kinds of formation shown in Figure 2.1.

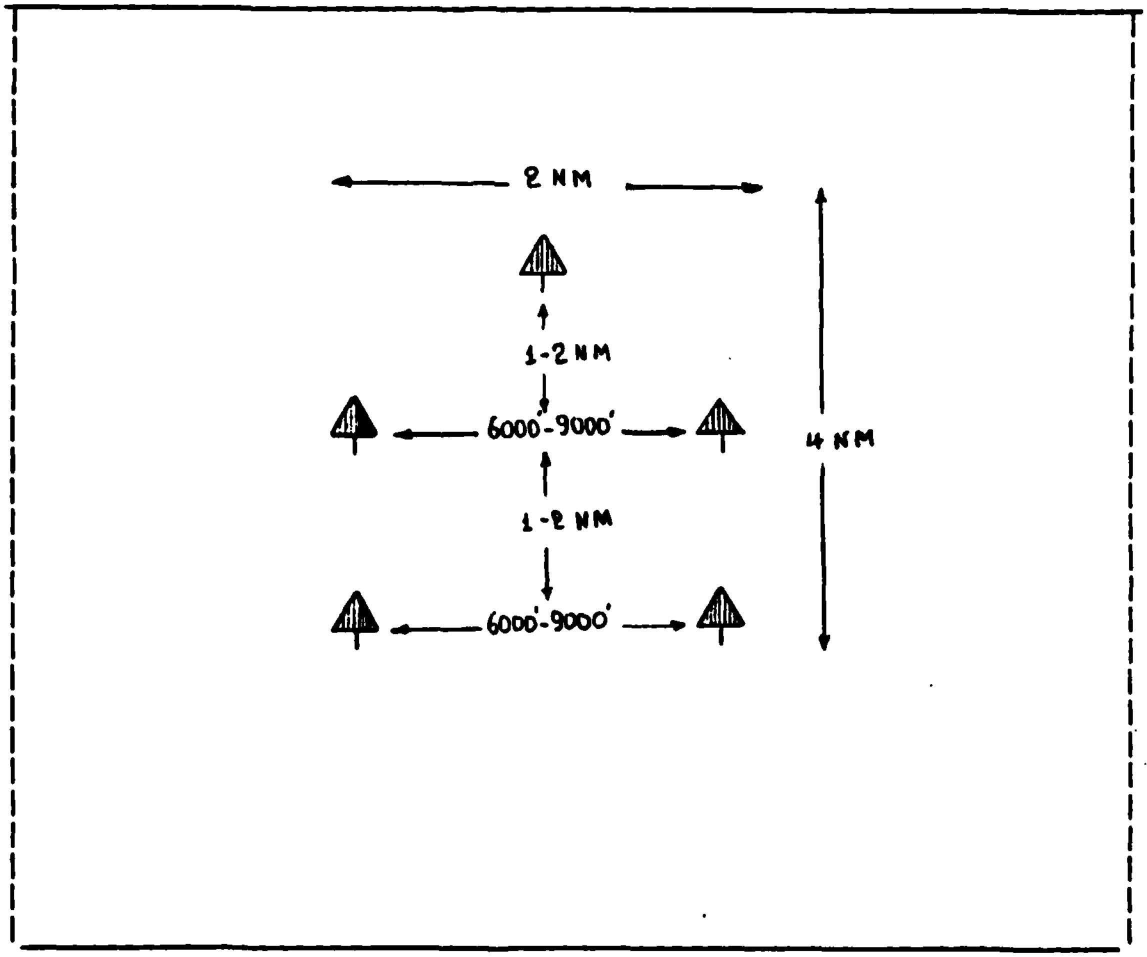

Figure 2.2 Formation of Five A/C

Both formations have three a/c, but formation one has dimensions approximately 1/3 by 1/3 NM while formation two is 2 NM by 2 NM. Because formation one is smaller, it is more flexible and it can use terrain masking better than formation

two. Thus, if the attack formations are of the first type, greater terrain modeling accuracy will be required.

2. Number of A/C

The number of a/c in a given formation also influences the terrain accuracy. The formation in Figure 2.2 above is similar to formation two in Figure 2.1; however, the number of aircraft has been increased. In this case, the five aircraft are flying in a formation which is 4 by 2 NM. This type of formation is less flexible and must fly higher. As a result, less terrain simulation accuracy is required. In particular, the dimensions of the grid square have to be approximately equal to the dimensions of the formation.

3. Flight Level

The flight level used by the attacking formation is also critical to the determination of the terrain simulation accuracy. If the user wants to analyze attrition against extremely low flying aircraft, the terrain simulation must be of very high resolution in order to generate accurate predictions.

B. CALCULATION OF THE GRID SQUARE ALTITUDES

The first step in the procedure used here is to calculate a representation altitude for each grid square. To find the altitude of each grid square corner a map is needed. The desired accuracy of the terrain simulation determines the scale of this map. In general, any military map with scale 1:50,000, 1:250,000 or 1:500,000 is appropriate.

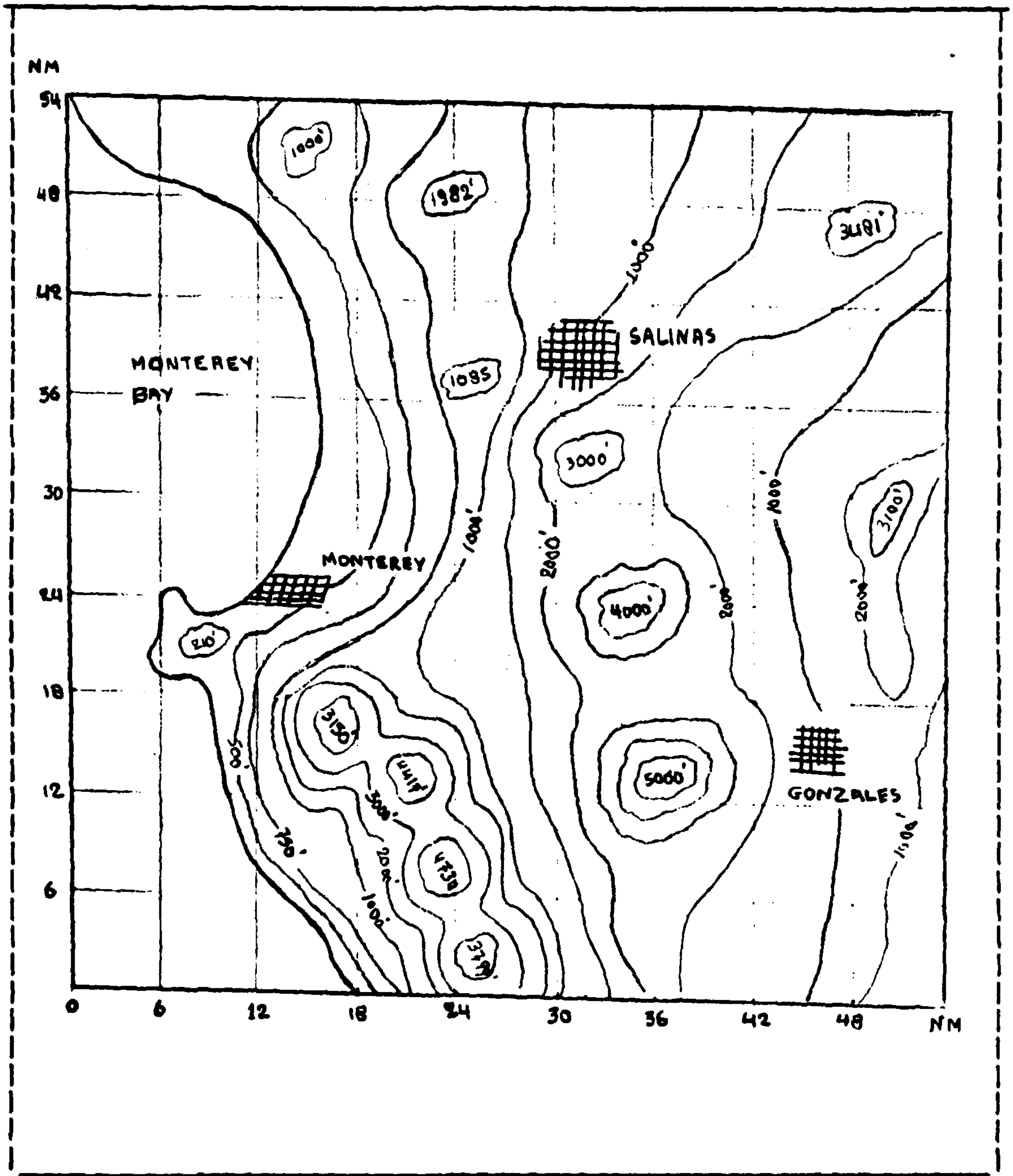

Figure 2.3 Terrain Divided into Square Grids

In Figure 2.3 a military map with a 1:500,000 scale is shown. Consider the map as an example of a defended area divided into grid squares. The size of each square is equal to 6 NM.

This map contains all the information needed for the average altitude calculation. It contains the scale of the ranges and enough contours to extract the heights of the four corners of each grid square in the following manner.

If one contour passes through a corner of the grid square assign the altitude of this contour to this corner. If no contour passes exactly through a corner, we interpolate the altitude between the two contours which contain the particular corner and assign that value to the corner in question.

Figure 2.4 shows an example. The grid square A B C D is used to calculate the average heights in this particular area. Contours pass through the corners A and D so the altitude 2,000 can be assigned to these two corners. For the corners B and C we have to interpolate the heights by using the contours 2,500 and 3,000 feet for point B and contours 3,000 and 3,500 feet for point C. A good approximation height is 2,700 and 3,250 feet for points B and C respectively.

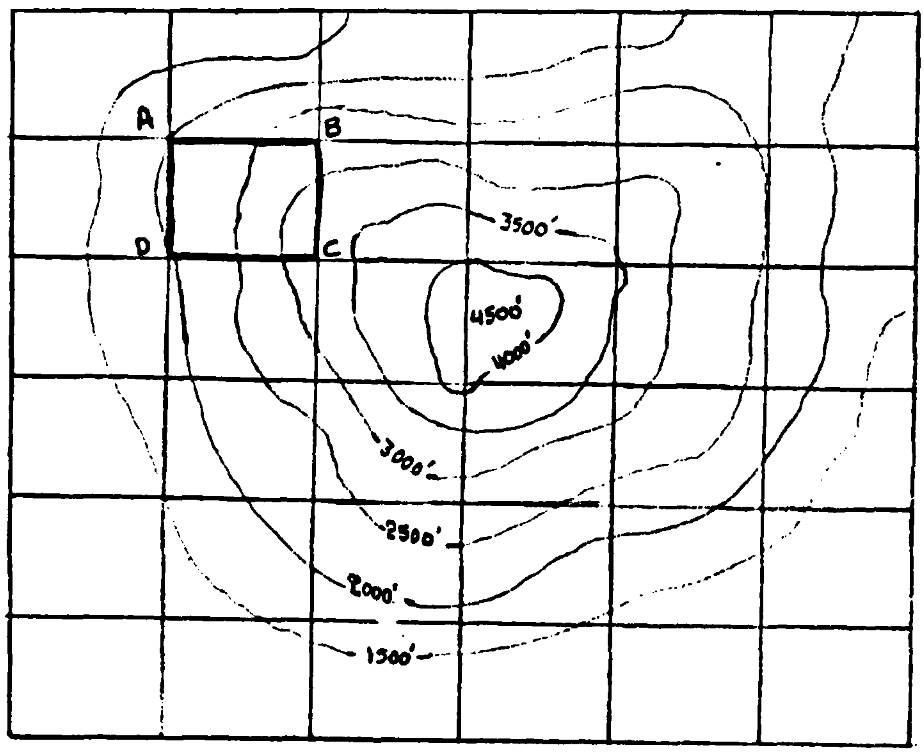

Figure 2.4 Grid Squares and Contours Curves

TABLE 1

ALTITUDES OF THE GRID SQUARE CORNERS

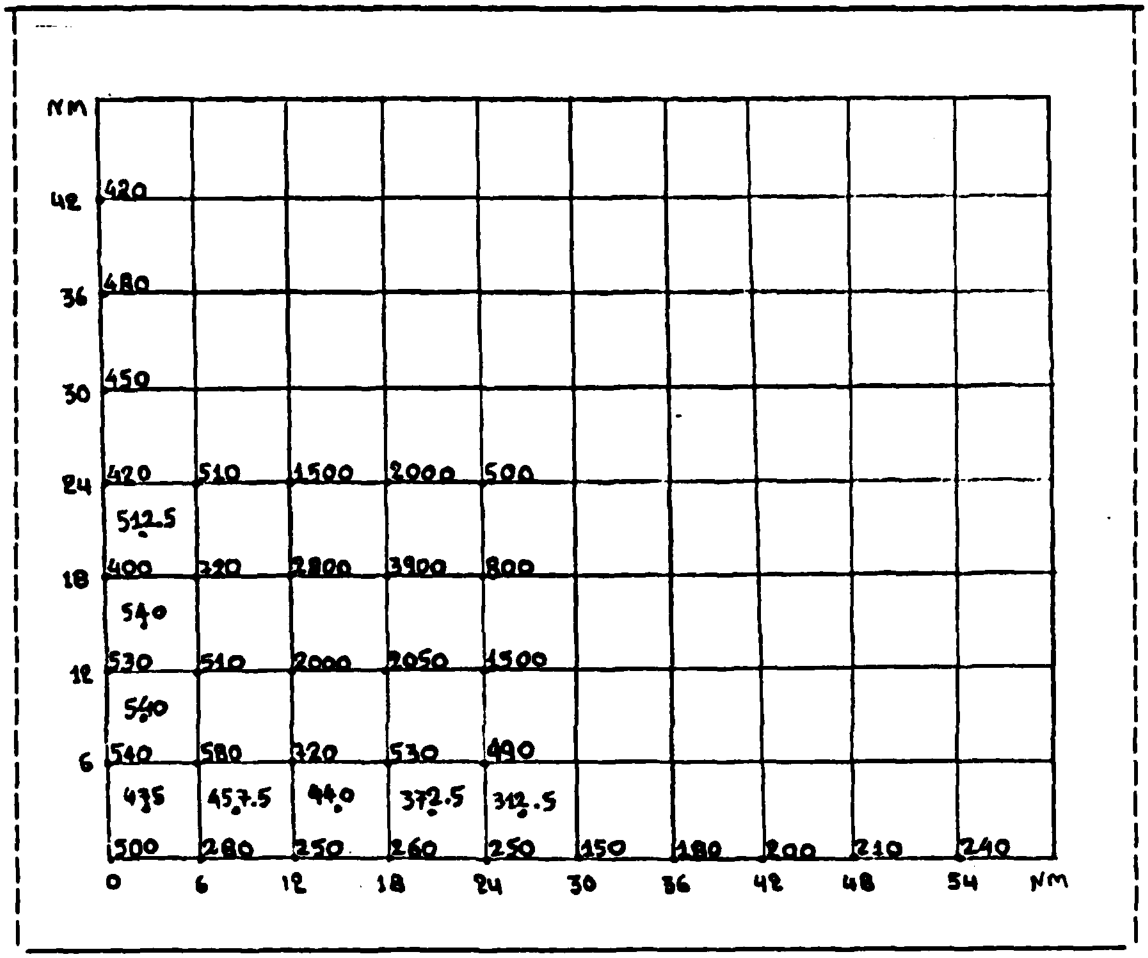

Table 1 shows the altitudes of the grid square corners of the terrain shown in Figure 2.3.

To find these altitudes is cubersome work but it must only be done once. Later average altitudes can be calculated for each grid and a data matrix can be stored to be used for many simulation purposes. Table 2 shows the average altitude of each grid square. After the calculations have been made

in this particular model, each average altitude represents the altitude of a 6 by 6 NM area.

TABLE 2

AVERAGE ALTITUDES OF GRID SQUARES

512.5	790	810							
540	820	1080	1017						
540	555	1150	950						
475	457.5	440	372.5	312.5					

NM: 30, 24, 18, 12, 6

0 6 12 18 24 30 36 42 48 54 NM

Figure 2.5, shows the plot of terrain made by a computer by using the data in Table 2 and the program in Appendix A. In this figure we can see Monterey Bay and most of the contours which are shown in Figure 2.3 above.

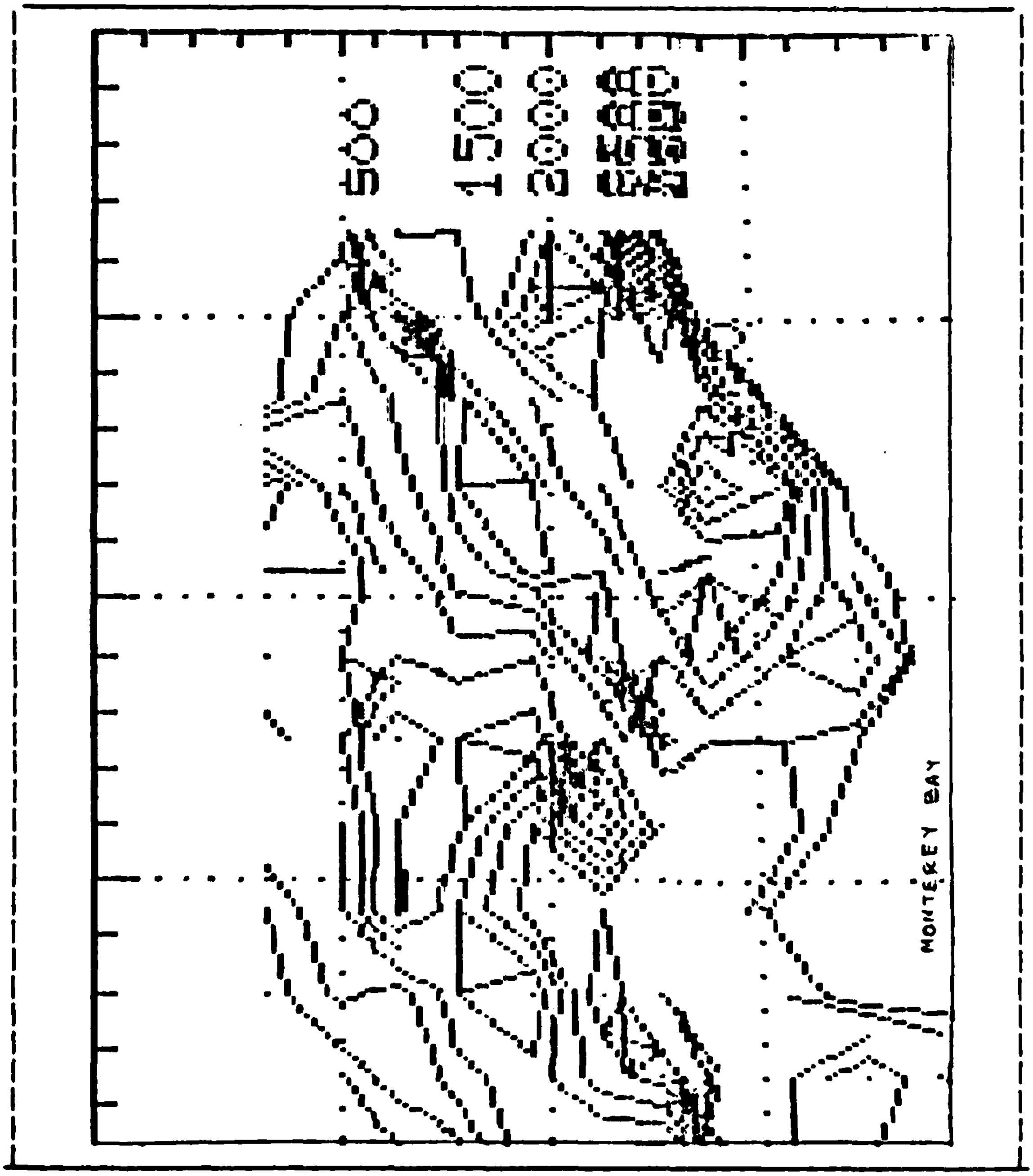

Figure 2.5 Plot of Terrain

C. ADVANTAGES AND DISADVANTAGES OF GRID SQUARE METHOD

1. Advantages

This method is very simple. It does not require difficult mathematical formulas on extensive calculations.

All computations can be done off-line and can be used in many different types of simulations.

The computer program which calculates the average altitudes - shown in Appendix A - can be used in any terrain situation.

2. Disadvantages

The method is discrete. When the average altitude of the grid square is calculated, it is used to represent the altitude for any point inside this area. Figure 2.6 compares the actual terrain with the grid square approximation. The terrain is divided into columns whose bases are squares 6 by 6 NM. By examinimg the points a and b in column 4, we can see that this method may sometimes overestimates (point b) or underestimates the actual terrain height (point a). This disadvantage can be eliminated by decreasing the length at the side of the square grid, but with the rsulting increase in computation.

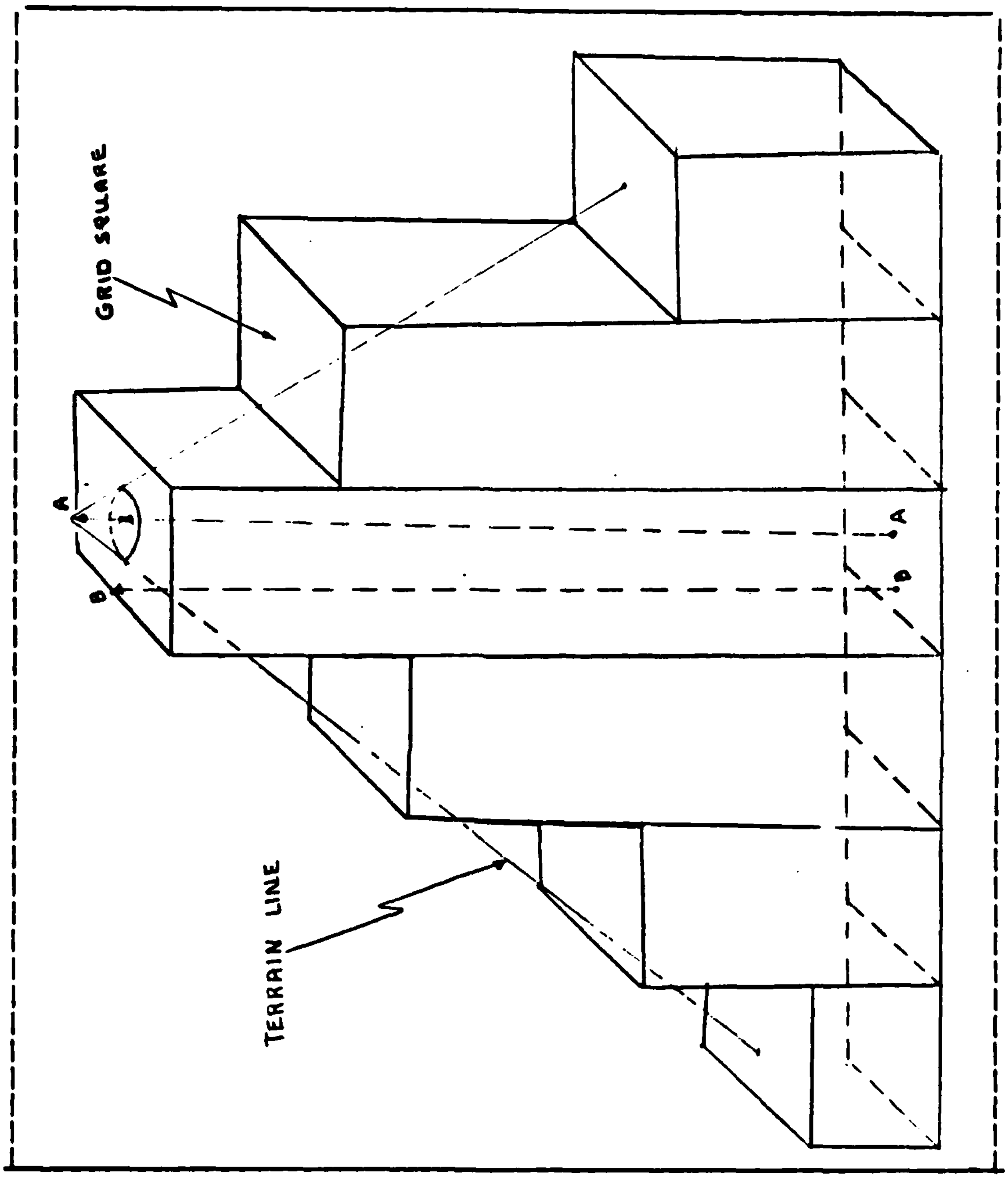

Figure 2.6 Terrain Represented by a Grid Square

III. CONSTRUCTION OF A MINIMUM ALTITUDE GRID

A. INTRODUCTION

The possibility that a radar site will detect a target which penetrates its area depends critically on its ability to "see" in the space where the target flies. Usually, especially in high threat areas, the attacking aircraft use terrain masking to avoid radar detection. On the other hand, radar sites try to improve the ability to "see" as low as possible by using more sophisticated equipment. Both radar sites and aircraft are concerned about the minimum altitudes that a particular radar can detect a target. Radar sites can use this information to find out their limitations and to design the area defense in better way. The attacking a/c can use the minimum altitude grid to plan their penetration route through the enemy area and take advantage of terrain masking. These routes must be planned to avoid radar detection, to save fuel, and to decrease the possibility of navigational errors.

This chapter will develop a model for calculation the minimum altitude grid. This minimum altitude grid will be used in the next chapter to determine radar line-of-sight and the possibility of detection.

B. DESCRIPTION OF THE MODEL

Consider the average altitude grid shown in Figure 3.1.

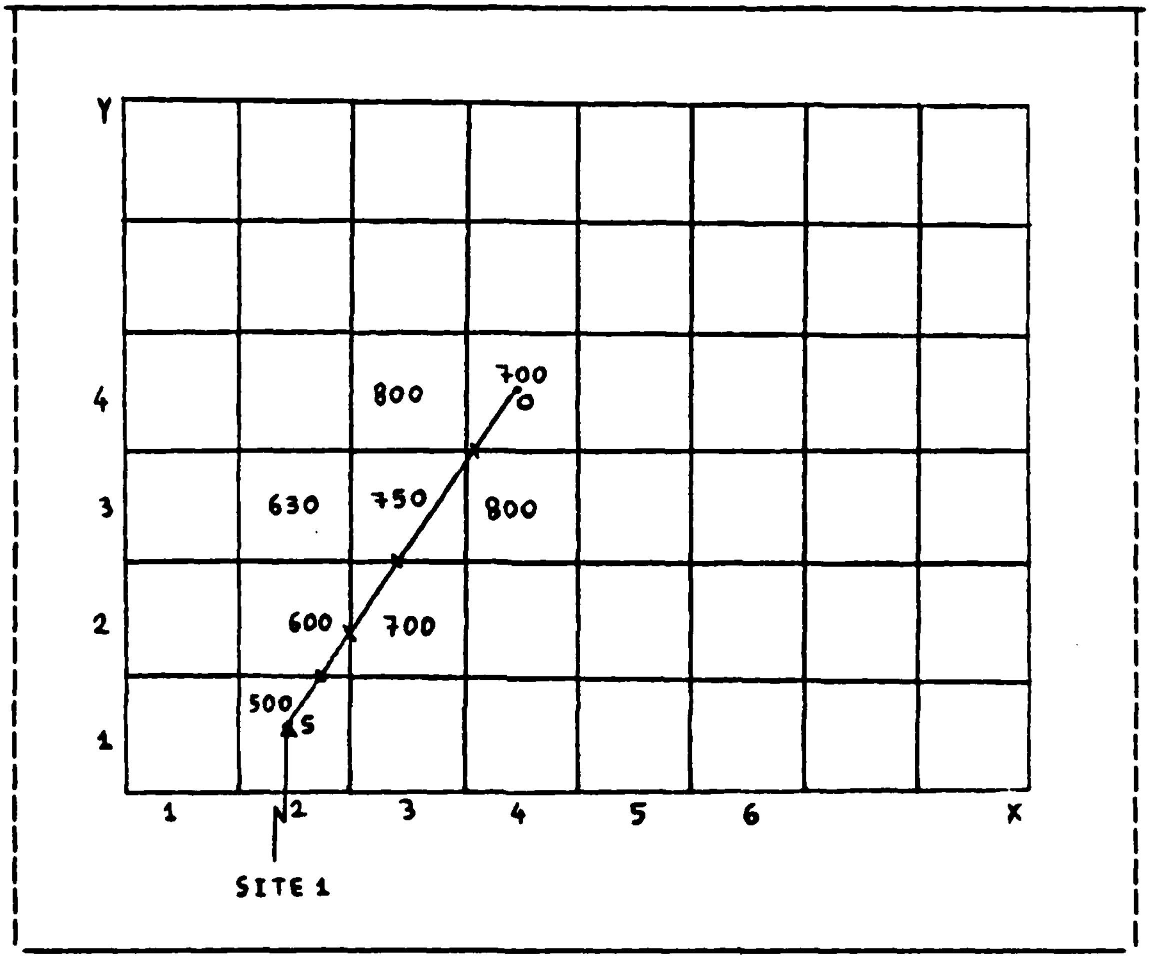

Figure 3.1 Average Altitude Grid

The line-of-sight from site 1 (S) to the center of grid (O) square (4,4) will be analysed.

This line starts from the position of site 1, passes through the grid (2,2), (3,2), (3,3) and ends at point (4,4). A profile of this line-of-sight is shown in Figure 3.2.

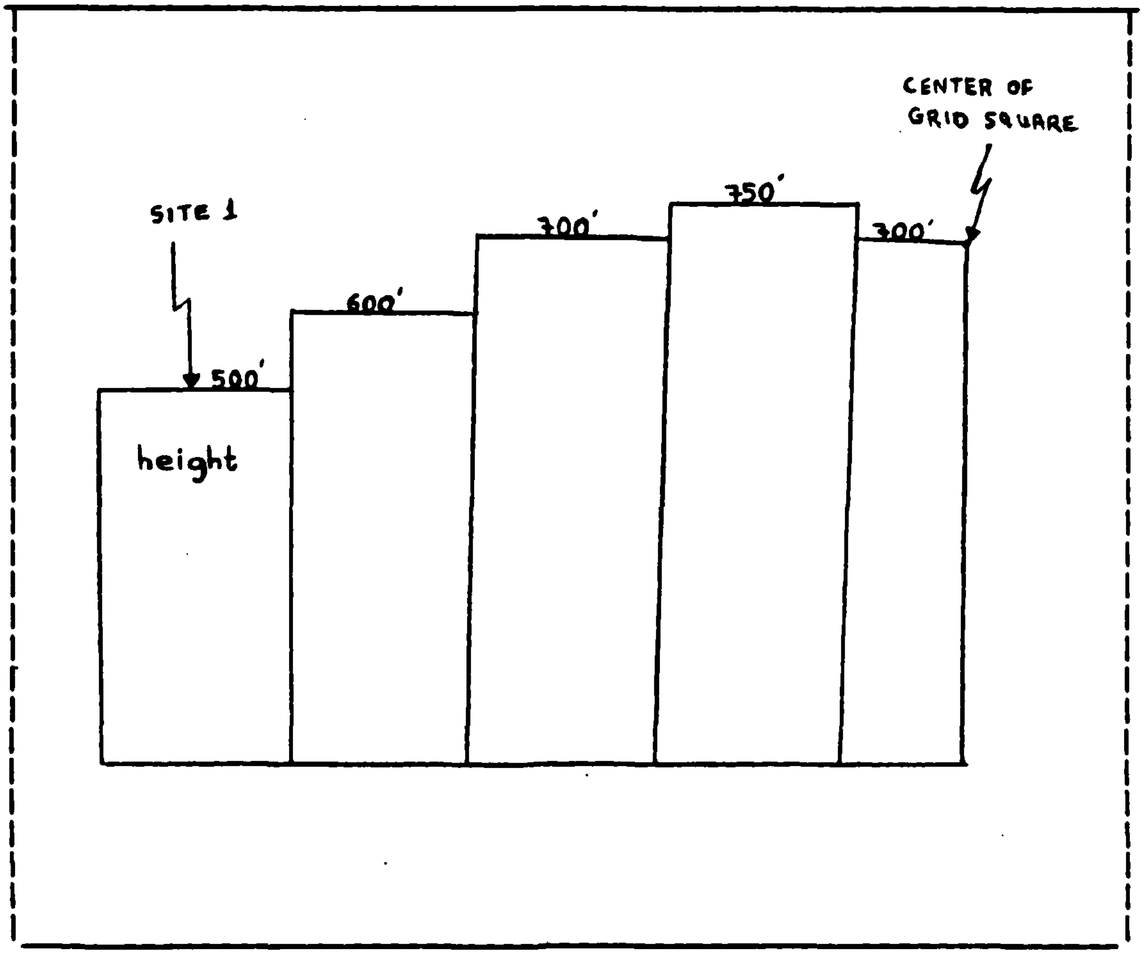

Figure 3.2 Profile of Average Altitude

The profile can be adjusted for earth curvature, as shown in Figure 3.3. Drawing a ray, AB, from site 1 through the edge of the first block illustrates the terrain masking that the first terrain block creates. Based on the first grid square masking, the minimum altitude required for radar line-of-sight to a target flying over grid square (4,4) will be calculated. The geometry of this situation, considering the grid (2,1) position and the grid (4,4) position, is shown in Figure 3.4.

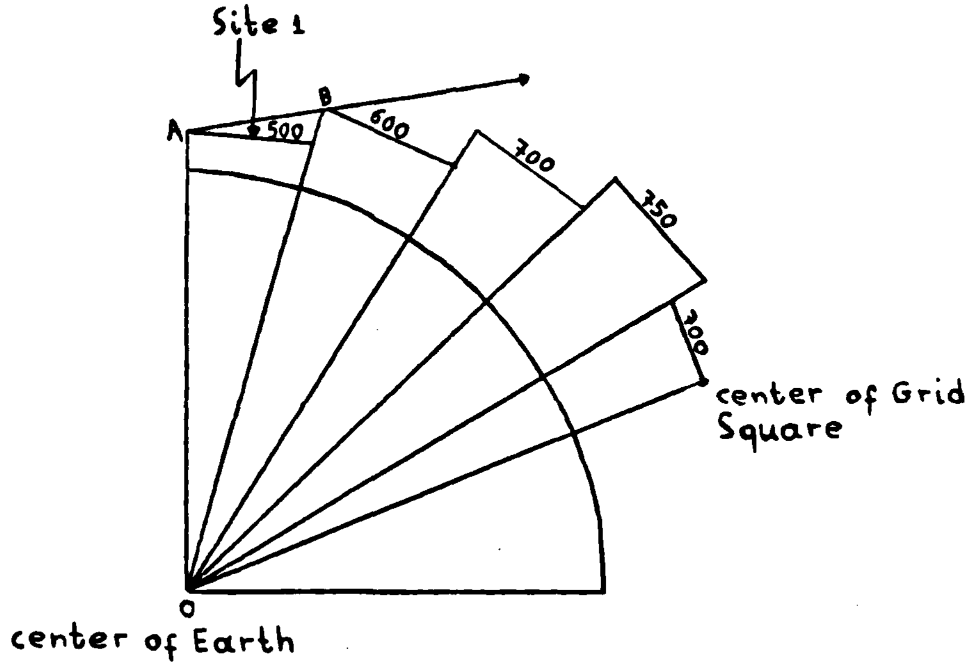

Figure 3.3 Profile of Average Altitude Adjusted For Earth Curvature

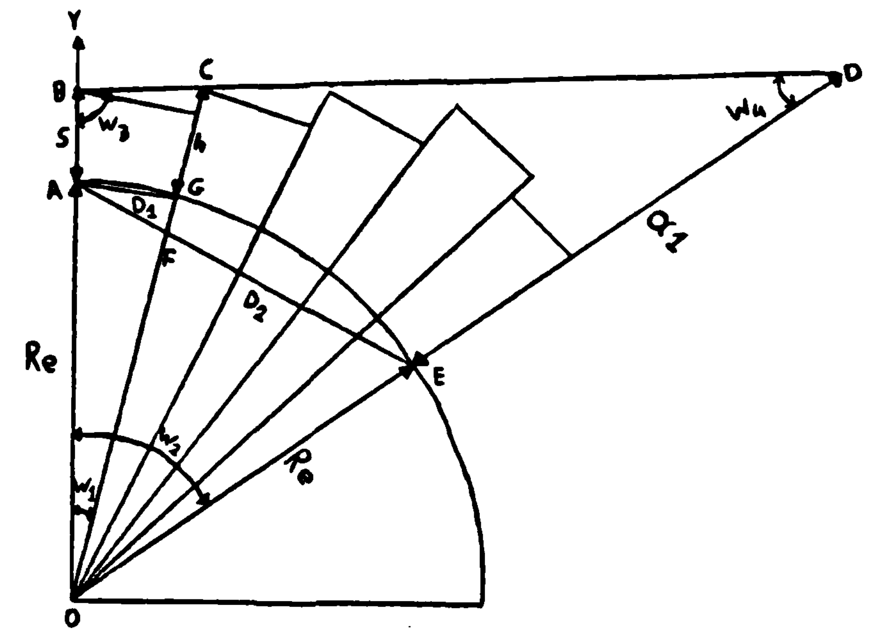

Figure 3.4 Calculating Minimum Altitude a1

1. Calculation of Distances D1 and D2

Let

Re = Radious of earth

D1 = Distance (AG) between radar site 1 and the edge of the first grid (2,1)

D2 = Distance (AF) between radar site 1 and grid (4,4)

S = Average altitude of radar site 1

h = Average altitude of (2,1) grid

al = Minimum altitude that the radar site 1 can "see" due to the grid (2,1)

The length of the arcs AG and AE can be calculated by using the formula:

$$ARC(AG) = ((X2-X1)^2 + (Y2-Y1)^2)^{1/2}$$

$$ARC(AE) = ((X3-X1)^2 + (Y3-Y1)^2)^{1/2} \qquad (1)$$

Where:

X1, X2 = the cartesian coordinates of radar site 1.

X1, Y2 = the cartesian coordinates of grid (2,1)

X3, Y3 = The cartesian coordinates of grid (4,4)

The angles W1 and W2 can be found by using the formula:

$$W1 = \frac{ARC(AG)}{Re} \text{ (in rands)} \quad , \quad W2 = \frac{ARC(AE)}{Re} \qquad (2)$$

The distances D1 and D2 can be now calculated by using the law of cosines:

$$(D1)^2 = (OA)^2 + (OG)^2 - 2(OA)(OG)COS(W1) \qquad (3)$$

Substitution of OA=OF=R, ARC(AG), ARC(AE) and W1 from formulae (1) and (2) into formula (3) yields:

$$D1 = Re[2 - COS(\frac{((X2 - X1)^2 + (Y2 - Y1)^2)^{1/2}}{Re})]^{1/2} \tag{4}$$

In the same way the distance D2 can be found.

2. <u>Calculation of the altitude a1</u>

In order to calculate the altitude a1, we also need the distance BC and the angle W3. These two can be found as follows:

$$(BC)^2 = (OB)^2 + (OC)^2 - 2(OB)(OC)COS(W1) \tag{5}$$

From Figure 3.4 we can see that OB = R+S and OC = R+h. By using this result and the formula (2) we can rewrite formula (5) as:

$$(BC)^2 = (R+S)^2 + (R+H)^2 - 2(R+S)(R+h)COS(\frac{ARC(AG)}{Re}) \tag{6}$$

Now, we know the sides OB and BC of the triangle OBC, so we are able to find the angle W3 by using the law of cosines and formulae (5) and (6) :

$$W3 = ARC [\frac{(OB)^2 + (BC)^2 - (OC)^2}{2(OB)(BC)}] =$$

$$\mathrm{ARC}\left[\frac{(R+S)^{2}\,[1-(R+H)\cos(W1)]}{(R+S)^{2}+(R+h)^{2}-2[R+S][R+h]\cos(W1)}\right] \qquad (7)$$

We also have:

$$W4 = \quad -(W1+W2+W3) \qquad (8)$$

Finally, by using the law of sines we can find the altitude al as follows:

$$\frac{\mathrm{SIN}(W3)}{OD} = \frac{\mathrm{SIN}(W4)}{OB} \implies OD = \frac{\mathrm{SIN}(W3)(OB)}{\mathrm{SIN}(W4)} \implies$$

$$Re + al = \frac{\mathrm{SIN}(W3)(R+S)}{\mathrm{SIN}(W4)} \implies$$

$$al = \frac{\mathrm{SIN}(W3)[R+S]}{\mathrm{SIN}(W4)} - Re \qquad (9)$$

Thus, given R, S, h, D1 and D2, the minimum altitude required because of terrain masking by the first block can be calculated.

Formula (9) may give us negative altitudes. This can happen in the case, when the height of the radar site is much higher than the height of the first block.

Negative minimum altitudes mean that the radar site can "see" even below the surface of the earth. It is obvious

that in this case, we have to assign the average height of the target grid (4,4), namely 700 feet (see Figure 3.1).

To summarize, the complete algorithm for calculating the minimum altitude a1 is:

If a1 is greater or equal to zero, then store the result.

Otherwise store zero and continue to calculate a new a1 because of the second block

3. Calculation of the maximum altitude a1

As one proceeds across grid squares along the line-of-sight path in Figure 3.1, four grid blocks are encountered. Therefore, minimum altitude calculations would be performed four times. These four altitudes, a1 through a4, are shown in Figure 3.5.

The minimum altitude entry, a44 for grid square (4,4) in relation to site 1, is:

a44 = maximum (a1,a2,a3,a4). This procedure must be repeated for every grid square located within the max radar range of site 1. Then, the site 1 minimum altitude grid would be completed.

The program "MINALT" (MINimum ALTItude), described in Appendix B, calculates the minimum altitudes for a given radar site. A small output of this program is shown in Figure 3.6. The upper number of each square represents the average terrain altitude for this grid and the lower number represents the minimum altitude that the radar at site 1, located in grid (3,3), can "see". For example, the minimum

altitude for grid (5,5) is 876 feet instead of 562 feet because of the terrain masking that the grid (4,4) creates.

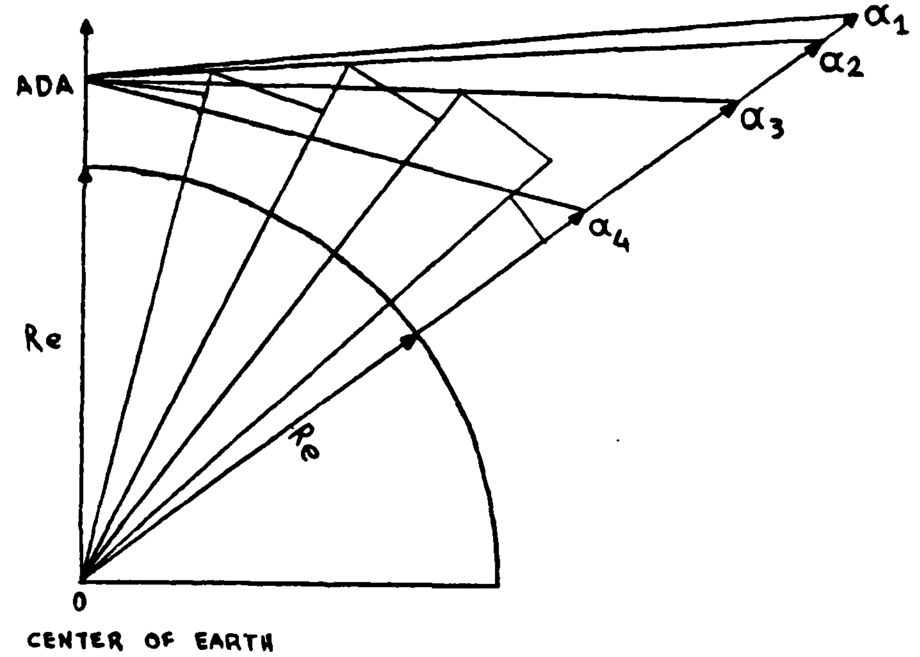

Figure 3.5 Minimum Altitudes along the Line-of-Sight

C. ADVANTAGES AND DISADVANTAGES OF THIS METHOD

1. Advantages

a. The calculation of the minimum altitudes al is performed by using precise computations. It is not an approximation.

b. The minimum altitudes have to be calculated once for each radar site. After that, these altitudes can be used for finding the line-of-sight. They also can be used as inputs to other models in a more complex simulation.

	1	2	3	4	5	6	7	8
7	0 / 0	0 / 0	140 / 140	490 / 490	787 / 892	625 / 1443	1000 / 1586	1812 / 4745
6	0 / 0	0 / 83	177 / 177	527 / 527	787 / 862	1312 / 1312	1312 / 3757	1587 / 4327
5	0 / 0	62 / 359	350 / 438	550 / 913	562 / 876	1425 / 2899	2075 / 3418	2275 / 4016
4	0 / 23	438 / 438	821 / 913	1000 / 1000	925 / 2176	737 / 2652	1637 / 3203	2262 / 3823
3	0 / 0	500 / 500	RADAR SITE	1625 / 1625	1620 / 2063	937 / 2565	725 / 3129	1162 / 3757
2	0 / 0	125 / 125	1375 / 1375	1625 / 2625	2500 / 3482	1625 / 3110	587 / 3801	337 / 3823
1	0 / 0	0 / 1617	750 / 1563	2375 / 3482	2875 / 4127	2150 / 5006	1200 / 6031	412 / 7163

Figure 3.6 Minimum Altitudes for Site 1 (3,3) - Elevation -

2. Disadvantages

In accurate line-of-sight determination, many calculations are necessary. However, if we consider that

these calculations will be done once and can be performed in a pre-processing stage, this algorithm poses no major problems.

IV. LINE-OF-SIGHT AND POSSIBILITY OF DETECTION

A. INTRODUCTION

All radars which operate in high frequencies have some restrictions which must be satisfied so that they will be able to detect a target flying across their area. The two most important restrictions are the existence of line-of-sight and the requirement that the target flies inside the maximum range of radar site.

This chapter will develop a method to find out if there is a line-of-sight for a particular radar site. It will also develop a model to determinate the possibility of detection of the target given that it flies inside the maximum range of the radar site.

B. LINE-OF-SIGHT DETERMINATION

Line-of-sight means that there is nothing between the radar site and target. Line-of-sight may be prohibited for two reasons.

First, terrain, such as hills and mountains, prohibit line of sight. Figure 4.1 below shows this case.

The second reason is the curvature of the earth. If the distance between radar site and target is lengthy then line-of-sight may be resticted due to earth curvature.

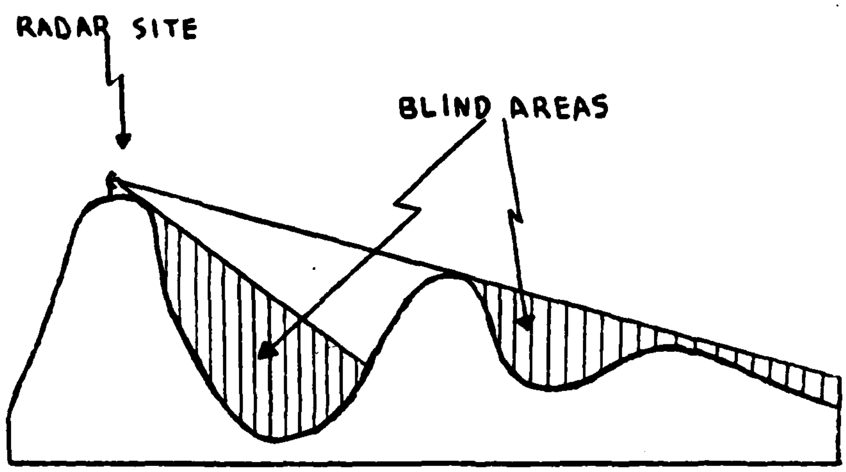

Figure 4.1 Line-of-Sight Restricted by Hill

This case is shown in Figure 4.2. As an example, when the altitude of the radar site is zero and the distance between radar site and target is 50 NM the target must fly approximately 2200 feet above ground in order to be seen by the radar site.

On the other hand, if the altitude of radar site is 1000 feet and the target's altitude is 2000 feet, the distance that the radar site will be able to detect the target is 87 NM.

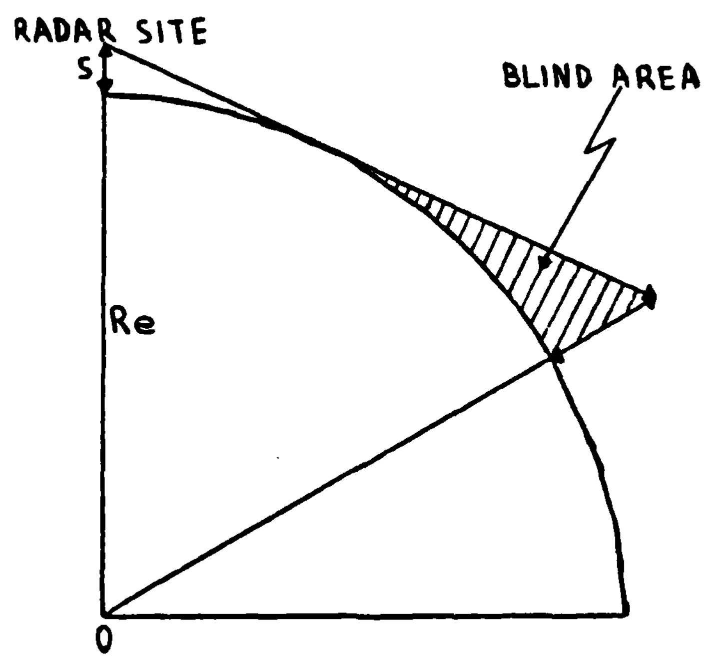

Figure 4.2 Line-of-Sight Restricted by Earth Curvature

In the program "CONTOUR" described in Appendix C, the determination of radar line-of-sight uses the minimum altitude look up table described in Chapter III. Figure 4.3 is the same as the Figure 3.6 in Chapter III. It contains the minimum altitudes that a/c over other grids must fly if radar site 1, located in grid (3,3), is to see a target.

Figures 4.4, 4.5 and 4.6 are outputs of the computer program "CONTOUR". The data used by this program are the data shown in Table 2 and Figure 3.6 in chapter II and III

respectively. Assume that the target flies at 500, 2000 and 6000 feet above the surface of the earth. This means that the target uses terrain masking. For example, if the average altitude of the grid (2,2) is 1000 feet and the target flies 500 feet above this grid, then the altitude of the target is 1500 feet. By comparing this altitude with the minimum altitude that the radar site can see in the grid (2,2) we can determine if there is line-of-sight.

7	0 / 0	0 / 0	140 / 140	490 / 490	787 / 892	625 / 1443	1000 / 1586	1812 / 4745
6	0 / 0	0 / 83	177 / 177	527 / 527	787 / 862	1312 / 1312	1312 / 3757	1587 / 4327
5	0 / 0	62 / 359	350 / 438	550 / 913	562 / 876	1425 / 2899	2075 / 3418	2275 / 4016
4	0 / 23	438 / 438	821 / 813	1000 / 1000	925 / 2176	737 / 2652	1637 / 3203	2262 / 3323
3	0 / 0	500 / 500	RADAR SITE LOCATION	1625 / 1625	1620 / 2063	937 / 2565	725 / 3129	1162 / 3757
2	0 / 0	125 / 125	1375 / 1375	1625 / 2625	2500 / 3482	1625 / 3110	587 / 3801	337 / 3823
1	0 / 0	0 / 1617	750 / 1563	2375 / 3482	2875 / 4127	2150 / 5006	1200 / 6031	412 / 7163
	1	2	3	4	5	6	7	8

Figure 4.3 Minimum Altitudes

In Figures 4.4, 4.5 and 4.6 we can see how the ability of the radar site increases as the altitude of the target increases. In these Figures there is a flight path which starts from grid (2,1) and ends at grid (11,9). In Figure 4.4, a target which is flying across this flight path, at 500 feet over the ground (using terrain masking), will not be detected by the radar site located at the grid (3,5). However, when the target uses the same path at 2000 feet, above ground level, it may be detected over the grids (3,2),(3,3),(4,3),(5,4),(6,5),(7,6),(8,6) and (8,7) (see Figure 4.5). If the target uses the same path at 6000 feet, above ground level, it will not be seen over the grids (10,3) and (11,3).

This method can be used to create a look up table for each site in the air defense system.

C. DETERMINING THE POSSIBILITY OF DETECTION

In the previous chapter we described the method for determining the existense of line-of-sight from the radar to the target. In this section, we will describe how to determine if there is a possibility of detection of the target by the radar site, given that there is line-of-sight. We use the term possibility of detection, because, even if there is line-of-sight and the target flies inside the maximum range of the radar site, radar may not be able to detect the target. For example, the performance of the radar could be reduced by heavy precipitation. In some cases, the target uses ECM which can degrade radar performance.

(NM)	1	2	3	4	5	6	7	8	9	10	11	
66	1	1	1	1	1	1	1	-1	-1	-1	-1	11
60	1	1	1	1	1	1	1	1	-1	-1	-1	10
54	1	1	1	1	1	0	0	0	0	-1	B -1	9
48	1	1	1	1	1	1	0	0	0	-1	-1	8
42	1	1	1	1	1	0	0	0	0	0	-1	7
36	1	1	1	1	0	0	0	0	0	0	-1	6
30	1	1	RADAR • SITE	1	1	0	0	0	0	0	-1	5
24	1	1	1	1	0	0	0	0	0	0	-1	4
18	1	0	0	0	0	0	0	0	0	0	-1	3
12	0	0	0	0	0	0	0	0	0	0	-1	2
6	0	A 0	0	0	0	0	0	0	0	-1	-1	1
	6	12	18	24	30	36	42	48	54	60	66 (NM)	

1 = Radar can "see" the target
0 = Radar can not "see" the target due to terrain masking
-1 = Radar can not "see" the target due to Max Range

Figure 4.4 Visible Area for Target Flying at 500 Feet

(N.M.)	1	2	3	4	5	6	7	8	9	10	11	
66	1	1	1	1	1	1	1	-1	-1	-1	-1	11
60	1	1	1	1	1	1	1	1	-1	-1	-1	10
54	1	1	1	1	1	1	1	0	0	-1	B -1	9
48	1	1	1	1	1	1	0	0	0	-1	-1	8
42	1	1	1	1	1	1	1	1	0	-1	-1	7
36	1	1	1	1	1	1	1	1	0	0	-1	6
30	1	1	RADAR SITE	1	1	1	0	0	0	0	-1	5
24	1	1	1	1	1	1	0	0	0	0	-1	4
18	1	1	1	1	1	0	0	0	0	0	-1	3
12	1	1	1	0	0	0	0	0	0	-1	-1	2
6	0	A 0	0	0	0	0	0	0	0	-1	-1	1
	6	12	18	24	30	36	42	48	54	60	66	(N.M.)

1 = Radar can "see" the target

0 = Radar can not "see" the target due to terrain masking

-1 = Radar can not "see" the target due to Max Range

Figure 4.5 Visible Area for Target Flying at 2000 Feet

N.M.	1	2	3	4	5	6	7	8	9	10	11	
66	1	1	1	1	1	1	1	-1	-1	-1	-1	1
60	1	1	1	1	1	1	1	1	-1	-1	-1	2
54	1	1	1	1	1	1	1	1	1	-1	-1 B	3
48	1	1	1	1	1	1	1	1	1	1	-1	4
42	1	1	1	1	1	1	1	1	1	1	-1	5
36	1	1	1	1	1	1	1	1	1	1	-1	6
30	1	1	RADAR SITE	1	1	1	1	1	1	1	-1	7
24	1	1	1	1	1	1	1	1	1	1	-1	8
18	1	1	1	1	1	1	1	0	1	1	-1	9
12	1	1	1	1	1	1	1	0	0	-1	-1	10
6	1	A 1	1	1	1	1	1	0	0	-1	-1	11
	6	12	18	24	30	36	42	48	54	60	66	N.M.

1 = Radar can "see" the target
0 = Radar can not "see" the target due to terrain masking
-1 = Radar can not "see" the target due to max Range

Figure 4.6 Visible Area for Target Flying at 6000 Feet

The procedure for deciding if a site can detect a given target involves the following steps.

1. Using a minimum altitude look up table, determine if there is radar line-of-sight to the target. If line-of-sight does not exist, no detection will occur.

2. If radar line-of-sight exists, calculate the slant range X, from the site to the target. If the slant range is more than the maximum acquisition range R of the radar, no detection will occur.

If the slant range is less than or equal to the maximum acquisition range, a detection is possible.

The calculation of the slant range can be performed as follows: (see Figure 4.7)

Consider a target at time t with the following parameters:

1. [X2(t), Y2(t)] is the target grid cordinates at time t

2. a(t) is the target altitude at time t

The lateral range D1 of the target from the site at time t is:

$$D1(t) = [(X1 - X2(t))^2 + (Y1 - Y2(t))^2]^{1/2}$$

Where (X1,Y1) are the grid coordinates of the radar site.

The angle W between ray OA and OB is D1(t)/Re, measured in radians.

The slant range X (AB) can be calculated from the law of cosines:

$$X^2 = (Re+S)^2 + (Re+a(t))^2 - 2(Re+S)(Re+a(t)COS(\frac{D1(t)}{Re})$$

Where S = the altitude of the radar site and Re = radiaus of the earth.

If $X^2 > Re^2$, no radar detection occurs.

If $X^2 < Re^2$, a detection is possible.

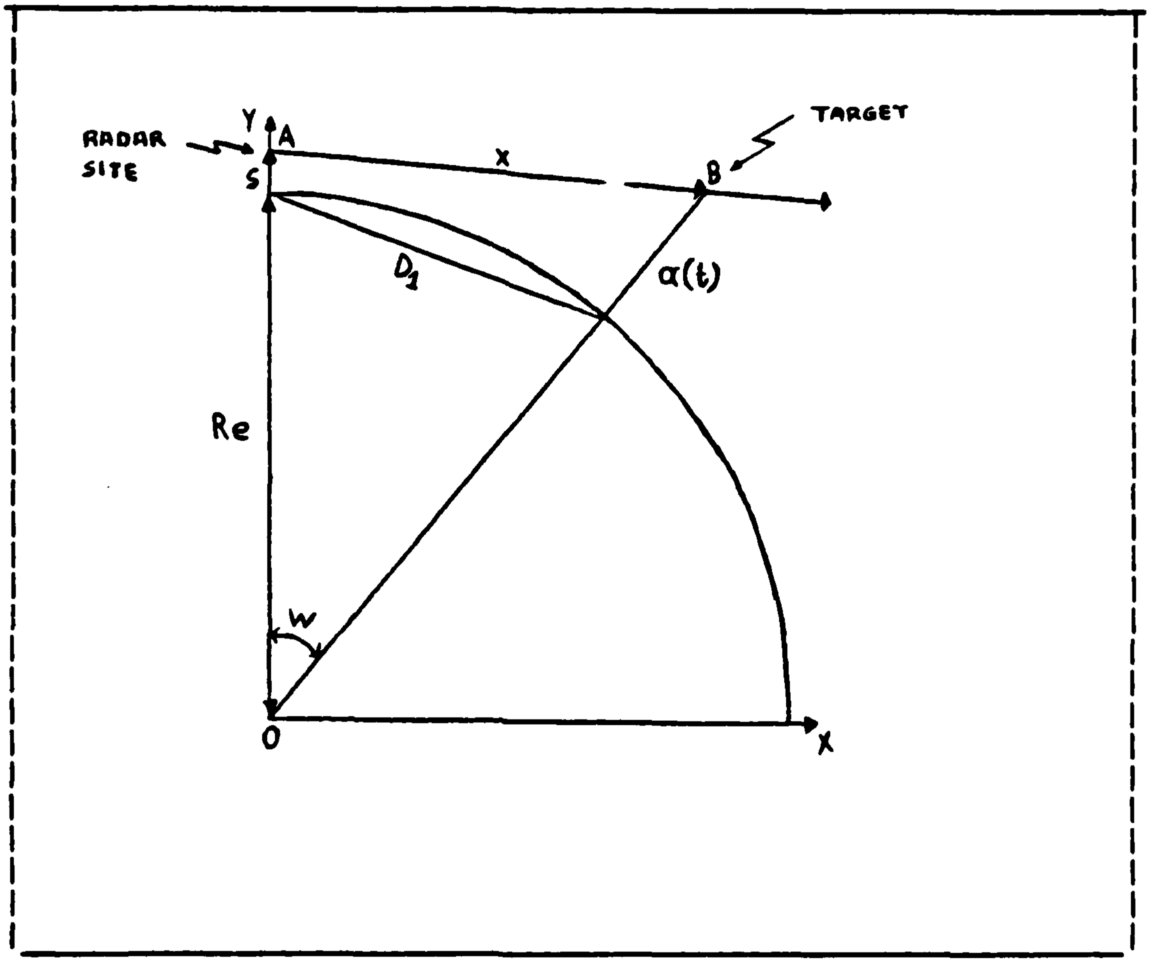

Figure 4.7 Calculation of the Slant Range

The computer program "CONTOUR", explained in Appendix C, calculates the possibility of detection. Figures 4.4, 4.5 and 4.6 are outputs of this program. This output will later be used by the target movement simulation.

D. ADVANTAGES AND DISADVANTAGES

1. Advantages

Determination of radar line-of-sight and possibility of detection for a given radar site and target altitude has to be done only once.

Figures like 4.4, 4.5 and 4.6 can be used by pilots to plan their routes. They can choose a flight altitude to minimize possible detection. This result is extremely useful to the pilots and it may be one of the most important spinoffs of this thesis.

This procedure can be employed in air models as well as other military models which are interested in determining line-of-sight.

2. Disadvantages

Since the model uses the average grid square altitudes given by the computer program "TERRAIN" described in Chapter II it is not an accurate calculation. The determination of line-of-sight is therefore an approximation. However the approximation becomes better and better as the dimensions of the square grid are reduced.

V. A/C MOVEMENT MODEL

A. INTRODUCTION

The tactics used by the aircraft to penetrate the hostile area is one of the most important factors affecting the probability of survival. The flight path chosen across the enemy country depends on the threat. For example, if there are radar sites along the aircraft route, the penetration flight path may consist of small connected paths in order to minimize detection. On the other hand, if there is no radar threat, long straight paths are chosen in order to minimize navigational errors and the time it takes to get to the objective.

B. DESCRIPTION

The simulation of aircraft movement can be performed in several ways. It is possible to design the simulation so that many of the detailed calculations can be accomplished off-line. Like the other models in the previous chapters, the aircraft movement model chosen here is performed totally off-line. Aircraft flights can be planned to take advantage

Aircraft flights can be planned to take advantage of terrain masking. A typical flight path was shown in Figure 5.1.

A flight path can be described as follows:

- Start time of enemy area penetration.
- Initial position.

- Heading of each leg of flight.
- Distance of each leg of flight.
- Speed of each leg of flight.
- Altitude of each leg of flight.

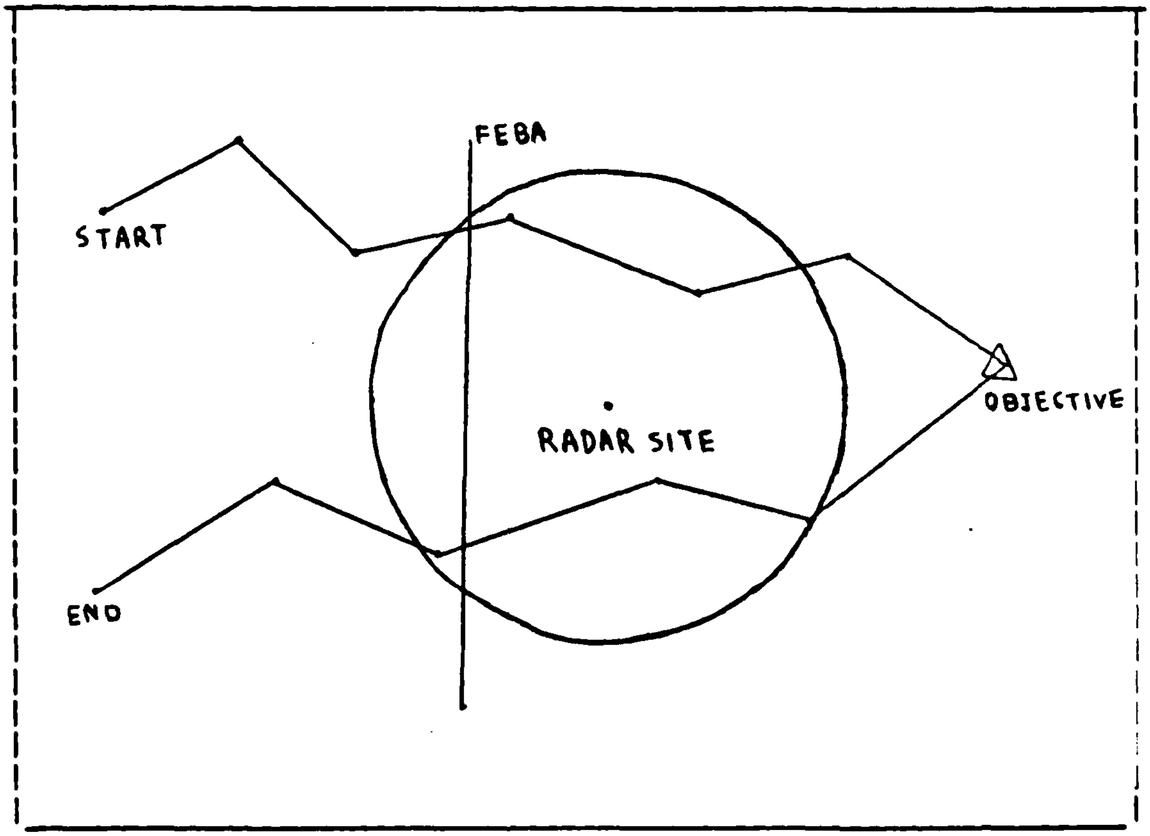

Figure 5.1 A Typical Flight Path

1. Start Time of Enemy Area Penetration

In actual air battles, the time attacking formations choose to enter the hostile area depends on the target and the enemy defense system. For example, if the enemy uses a missile defense system, the attacking aircraft may attack during daylight in order to use terrain masking.

In this model, the start time of the first penetrating attack formation is arbitrary. For example, if the first a/c enters the hostile area at 07:00 o' clock in the morning, then this is considered to be time zero. If a a second formation crosses the enemy area at 07:30 then, its time start t is 30 minutes. For computation purposes, the time steps from 07:00 to 07:30 are filled with zeros, so that the air combat model knows that this particular formation enters the battle at 07:30. In Figure 5.2 the fixed time is 07:00 so the start time of the formation is 30 minutes. In the simulation model "MOVEMENT", described in Appendix D, the start time is prompted and it must be entered in minutes.

2. Initial Position

The point that the attacking aircraft use to cross the Forward Edge of Battle Area (FEBA) is very important. If the enemy area is protected by radars, then the initial point must be chosen to minimize detection.

In this air combat model, the FEBA is the line defining the area where attacking aircraft are subject to attrition. This line is chosen by the model designer and it depends on the enemy interception capability. For computation purposes, this line is represented by the Y axis of the Cartesian coordinate system. The X axis is the bottom boundary of the enemy area which is to be simulated. In Figure 5.2 a 48x30 NM enemy area is shown. The (0,0) point is the lower left point of the map. The point that any attacking formation uses to penetrate the hostile area is

described by its relation to (Ø,Ø) point of the coordinate system. For example, in Figure 5.2, the start point for the formation is (Ø,5), which means, that the formation crosses the FEBA 5 NM north of the (Ø,Ø) point. In the same fashion, any other point of the formation is described by relating to (Ø,Ø) point. For example, the new point (39,2) of the formation in Figure 5.2 means that the formation enters the simulated battle again, after attacking the target, at the point 39 NM east and 2 NM north of the (Ø,Ø) point. In the "MOVEMENT" model for each segment in the flight path, the initial point of aircraft penetration is prompted and it must be entered in NM.

3. Heading of the Flight Path

The heading of the flight path depends on the terrain masking that the pilot wishes to use. Usually, when the pilot wants to avoid radar detection, he tries to find routes inside the hostile area that gives him the maximum protection.

For computation purposes, the direction is computed by measuring the angle between Y axis and flight path. In Figure 5.2 the angle between Y axis and the first flight path (OA) is 6Ø degrees. In the "MOVEMENT" model, for each segment of the flight path, the direction of the a/c movement is prompted and it must be entered in degrees.

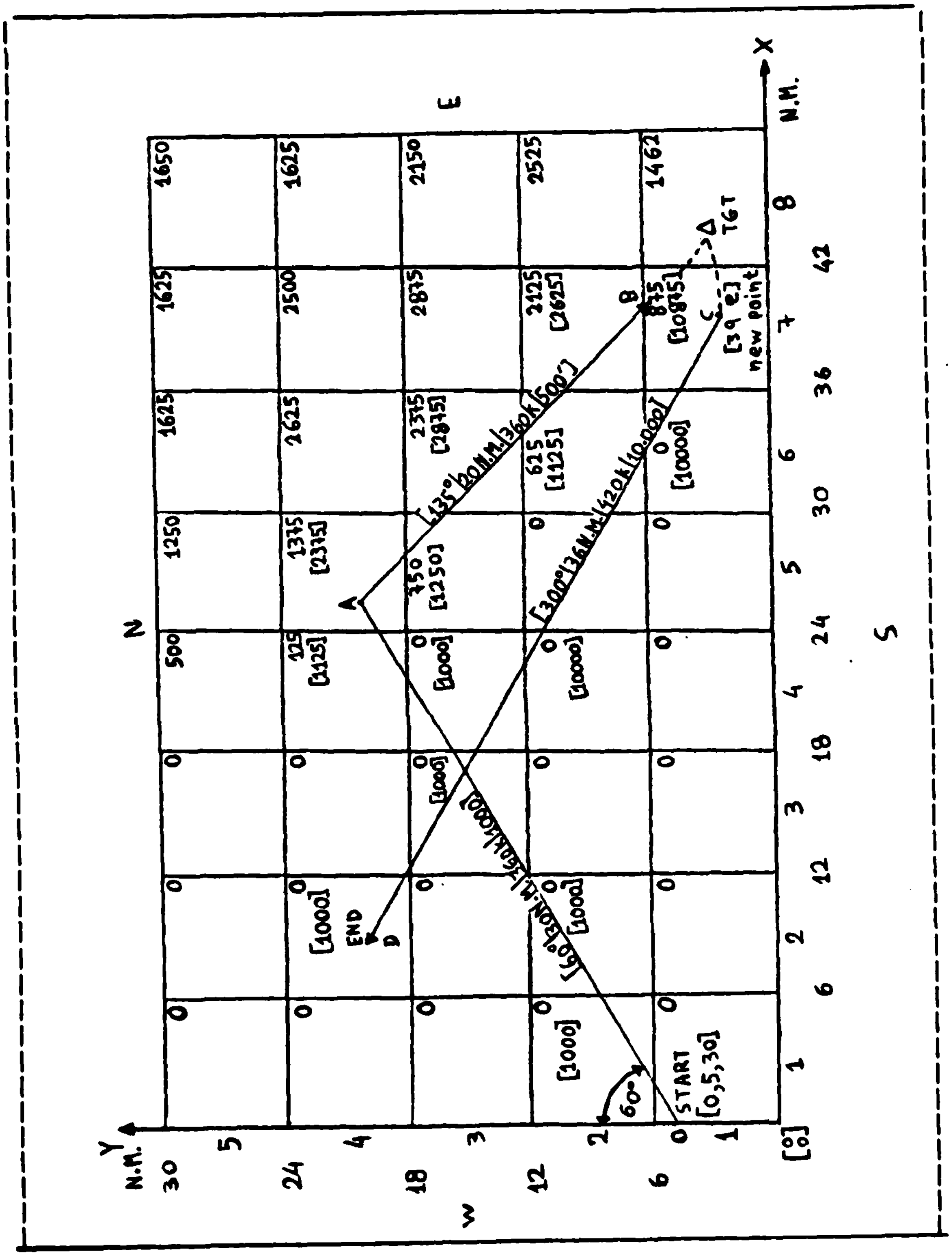

Figure 5.2 Flight Path Design

4. Distance

Like the heading, the distance depends on the desired terrain masking. The more terrain masking, the shorter the distance of each flight path. In an extreme case, if the pilot wants to take full advantage of terrain masking, he must follow the terrain form and continually change course. Under these conditions, however, there is a good chance that the pilot will lose orientation. On the other hand, the pilot can neglect terrain masking and fly the entire mission in one straight flight leg. However, his aircraft is much more easily detected and intercepted.

For computation purposes, the distance is computed by measuring the length of each flight path. In Figure 5.2, the distance of the first flight leg is 30 NM. In the "MOVEMENT" model, for each segment in the flight path, the distance is prompted and it must be entered in NM.

5. Speed

The speed that penetrating formations use is a function of many factors. A speed must be chosen to allow for the pilot to maneuver and to avoid interceptors. Fuel consumption and navigational errors must also be considered. Additionally, pilots use different speeds for penetrating the enemy area and for attacking the target. In Figure 5.2 the first two flight legs are flown by using speed equal to 360 Knots and the third one, after the formation has attacked the target, is flown by using speed equal to 420 Knots.

For computation purposes, the speeds are chosen by the scenario designer for each flight leg. In the "MOVEMENT" model the speed for each flight path segment is prompted and it must be entered in Knots.

6. Altitude

Like direction and distance, the altitude depends on the terrain masking. A high speed, low level flight will minimize radar detection and interceptions. On the other hand, low level flights use more fuel which sometimes restricts the aircraft range capability. High altitudes are normally used during the return route in order to save fuel. For computation purposes, the altitudes are chosen by the scenario designer for each flight leg. In reality, the altitude is expected to be the most critical factor, as far as the attrition rate of the a/c is concerned. In Figure 5.2, the altitudes in each square grid are the average terrain altitudes. Also, the three flight legs use a height of 1000, 500 and 10,000 respectively. Finally the total altitude (average grid altitude + altitude of a/c above the terrain) is shown inside the parenthesis for each flight path and for each square grid. This total altitude will be compared in the next chapter with the smallest altitude for each site (computed in Chapter 4) to determine the capability of the radar sites to detect the attacking aircraft.

In the "MOVEMENT" model the altitude is prompted and it must be entered in feet above the terrain.

The a/c movement model is supported by the computer program "MOVEMENT" described in Appendix D. It uses inputs from other models and its output will be used for "FDETECT" and "PRIORITY" sub programs described in later chapters. The data necessary to run the "MOVEMENT" program are shown in Figure 5.2 above. In Table 3, an output of this program is shown. The first row is the time step, the second and third rows are the position of the a/c (X/Y), the fourth row is the altitude over each position. The fifth row is the direction of the flight legs.

TABLE 3

OUTPUT OF "MOVEMENT" PROGRAM

TIME STEPS:	1	2	3	4	.	.	.	N
X:	1	2	3	4	.	.	.	12
Y:	6	7	8	9	.	.	.	16
ALTITUDES:	1000	1125	2375	2875	.	.	.	10000
COURSES:	60	60	135	135	.	.	.	300

C. ADVANTAGES AND DISADVANTAGES OF THE A/C MOVEMENT MODEL

1. Advantages

a. The calculation of the a/c position (X,Y) is accurate (not an approximation).

b. The calculation for each target route has to be done only once and can be done off-line.

c. Since the movement model is independent of the air combat model, it can be used for other air models and simulations.

2. Disadvantages

a. The calculation of the altitude of each aircraft over its position is done by summing the average altitude of the terrain and the altitude of the a/c above the terrain. Since, the average altitudes are an approximation, then the altitude determination of the of the attacking aircraft are, similarly, an approximation.

VI. TARGET DETECTION, INTERCEPTION AND PRIORITY MODELS

In Chapter 4, the minimum altitude that a radar site can detect a target was calculated and in Chapter 5 the flight data (position, altitude, course, etc) were generated for each time step of the simulation. In this chapter, the analysis of the air model will be continued by combining Chapters 4 and 5 and by finding the points that a particular radar site can detect a specified target given by the airmodel simulation scenario. Furthermore, this Chapter will describe the interception model and target priority model which will help the radar site commander to determine missile firing capability against the target.

A. TARGET DETECTION MODEL

The purpose of the target detection model is to determine if there is line-of-sight between a particular radar site and a target and if it is within the radar site's maximum range. For this purpose, the target detection model combines the data given by the "MINIMUM ALTITUDE" model and the data given by the "A/C MOVEMENT" model. The "MINIMUM ALTITUDE" model, as described in Chapter 4, gives the minimum altitudes that a radar site can detect a target over its area. The "A/C MOVEMENT" model as described in chapter 5, gives the flight data of a target (a/c position, altitude, course, speed) flying across the enemy country.

The algorithm the target detection model uses the following steps:

1. It takes the position of the radar site and the position of a/c in time step I.
2. It checks to see if the distance between the radar site and the target is less than the maximum range of the radar site.
3. If no, set I = I+1 and go to step 1.
4. If yes, it compares the minimum altitude of the radar site with the minimum altitude of AC in grid square for detection by radar site 1. If the first altitude is smaller than the second, then a detection is possible. Set I = I+1 and go to step 1. If the first altitude is greater than the second one, no detection is possible. Set I = I+1 and go to step 1.

In Figure 6.1, the minimum altitudes of the radar site 1 (in parenthesis), the route and the altitudes of a/c are shown. By applying the above algorithm, a possible detection occurs in grid squares (1,7), (2,7), (2,6), (3,6), (3,5), (4,5) and (6,4). On the other hand, there is no detection in grid squares (1,8), (5,5), (6,5), (7,4) and (8,4) because the radar site can not see the target and in grid squares (8,5), (9,5) and (9,6) because the target is out of the maximum range of the radar site.

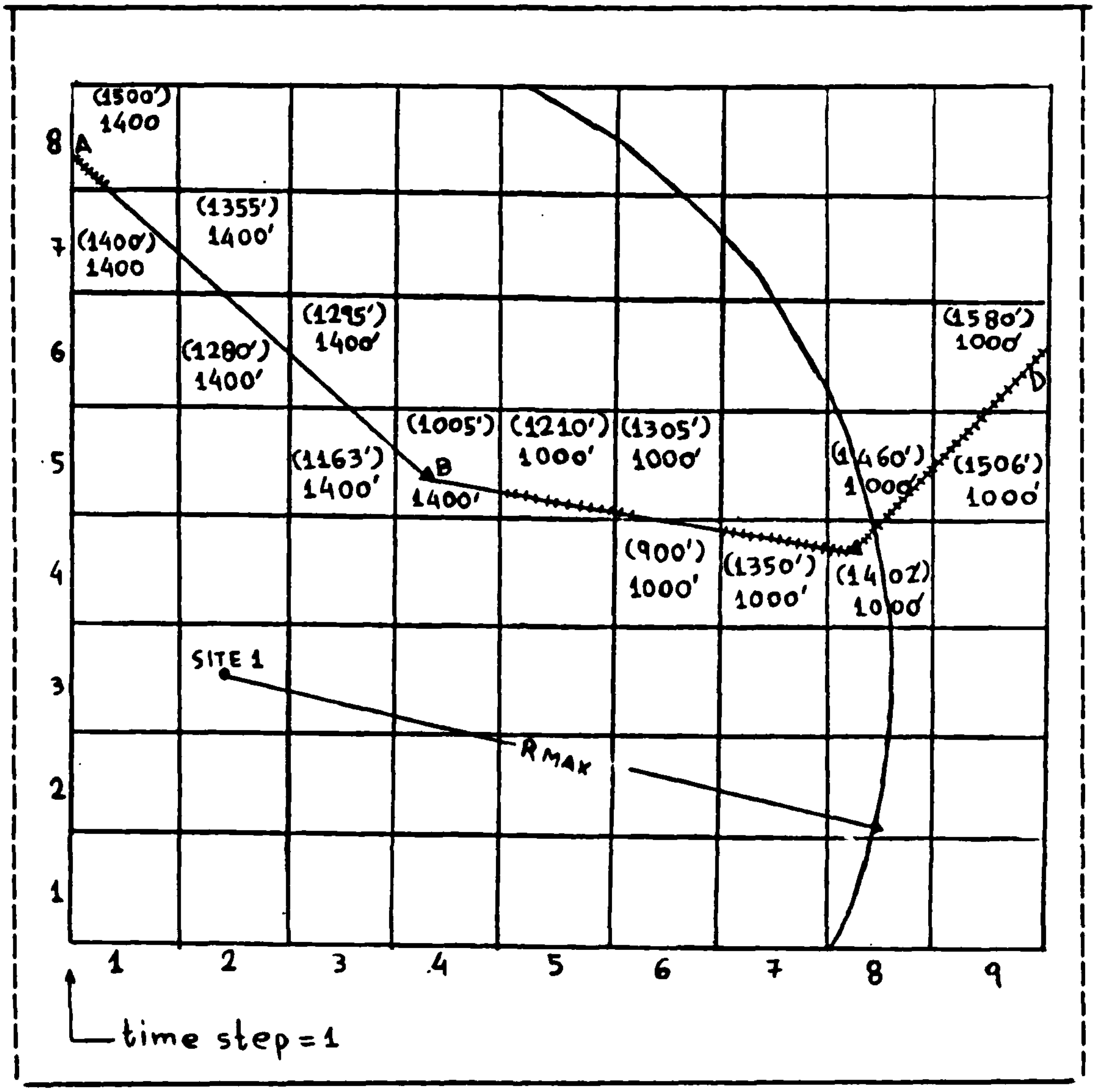

Figure 6.1 Radar Site-Target Flight Route Relation

In this way, the detection state vector is defined for each time step t and it has the following form:

$$D(t) = d1(t) , d2(t) , d3(t) ,.... dn(t)$$

Where n = number of targets in the scenario.

di(t) = Ø, when the site cannot detect target i.

di(t) = 1, when the site can detect target i.

The outcomes 1 or 0 are only a function of detection geometry and depend only on the maximum range and the minimum altitude of the radar site and the altitude of the target.

All the detection vectors form the detection matrices. Each radar site has its own detection matrix for all the targets. In Figure 6.2 such a matrix is shown:

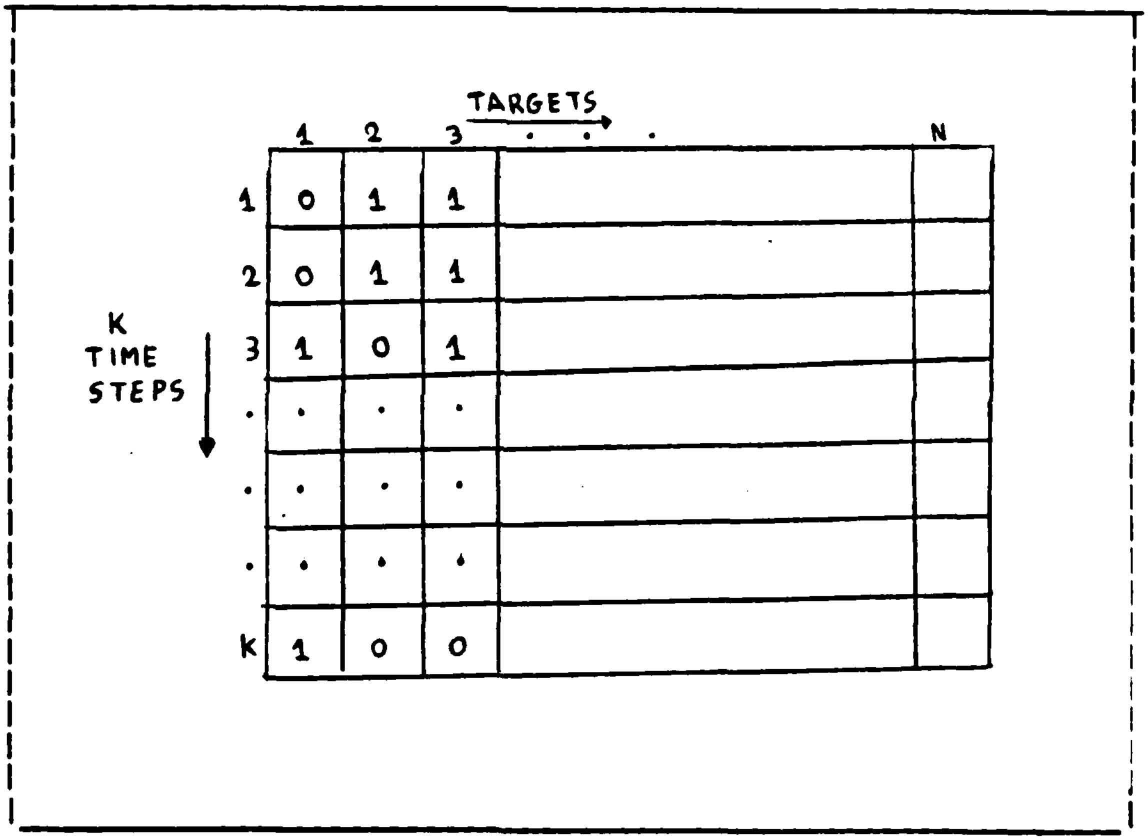

Figure 6.2 A Detection State Matrix for One Site

For example, the detection matrix for radar site 1, in Figure 6.1 for target 1, for time step 1 to 9 is (in row form to save space):

Time step: 1 2 3 4 5 6 7 8 9

Detection (Y/N): Ø 1 1 1 Ø Ø Ø Ø Ø

During the simulation at time step k, if the air model needs to find if the radar site 1 can detect the target 1, the only thing to be done is to check the element (k,1) in the detection state matrix of radar site one, to see if the value is Ø or 1.

The target detection model is supported by the computer program "FDETECT" (File DETECT) described in Appendix E. The purpose of the computer program is to construct the detection state matrix for each Radar site by prompting the following inputs:

a. The minimum altitudes of the radar site given by the "MINALT" program, described in Appendix C.

b. The flight data of the targets given by the program "MOVEMENT" described in Appendix D.

This computer program can be run for any radar site and for any number of targets.

B. TARGET INTERCEPTION MODEL

The next step, after the radar site has detected the target, is to start the procedure of intercepting it. In real war, the determination of whether the missile site can intercept the target or not is given automatically by the radar computer which solves the geometry of the interception considering all the needed paramaters. In simulation, a program is required to solve the geometry of the interception. Unfortunately, different kinds of

radar-missile sites use different methods of interception geometry. In Figure 6.3, two different methods are shown: The target following method and the interception point prediction.

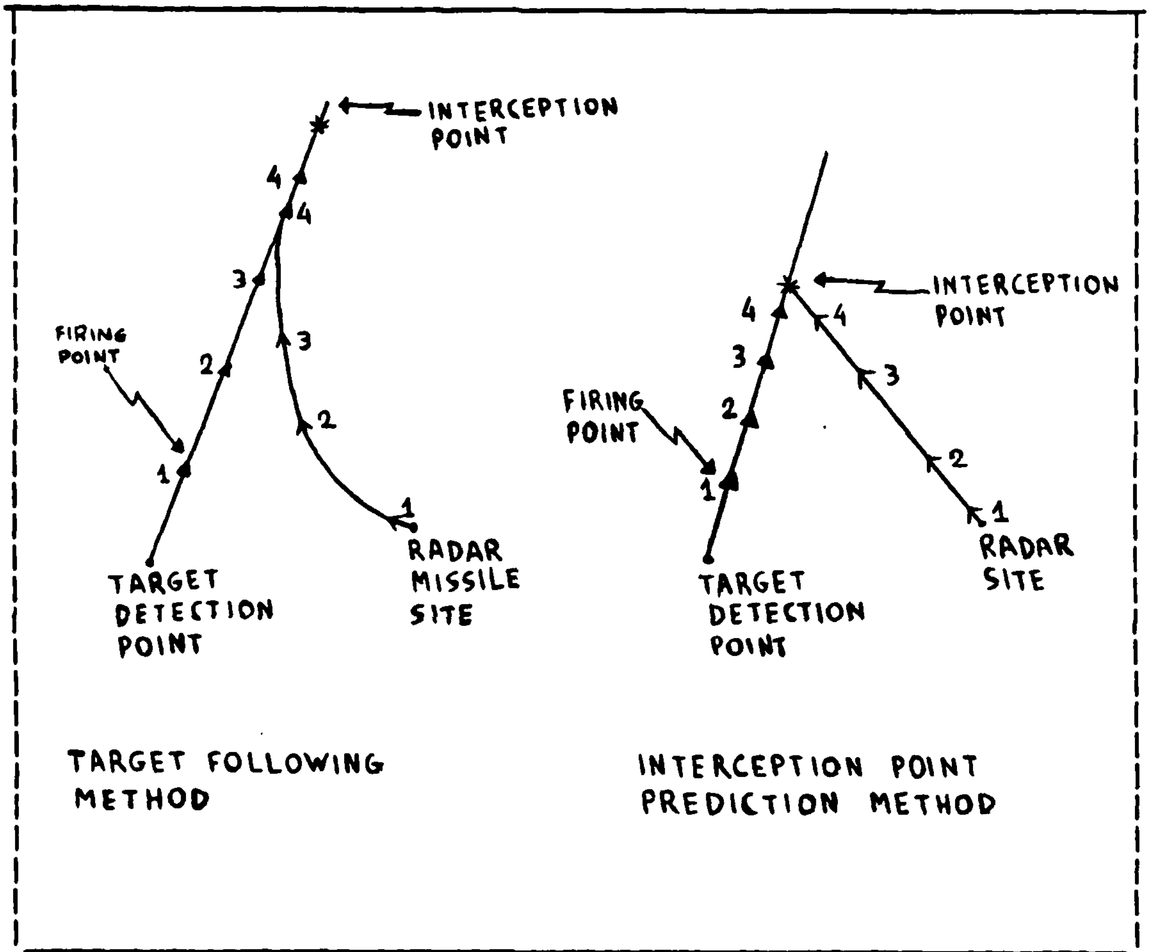

Figure 6.3 Two Methods of Interception Geometry

In first method, the firing missile follows the target until it reaches and kills it. This method is used by old radar missile systems or by missiles which use infrared radiation guidance system. The second method is used by the most modern radar missile systems and it is very

efficient because it minimizes the interception time. In this method the missile is guided to the point that the radar computer has calculated, so that the collision between target and missile will take place. The method is simulated in this air model and it is described here.

To predict the point at which a launched missile and the target will collide is not difficult. This point depends on the distance (D) between target and radar-missile site, on the angle (W) between flight path and radar-missile site and on the speeds of the target and the missile.

In Figure 6.4 the analyzed geometry of the interception point prediction method is shown:

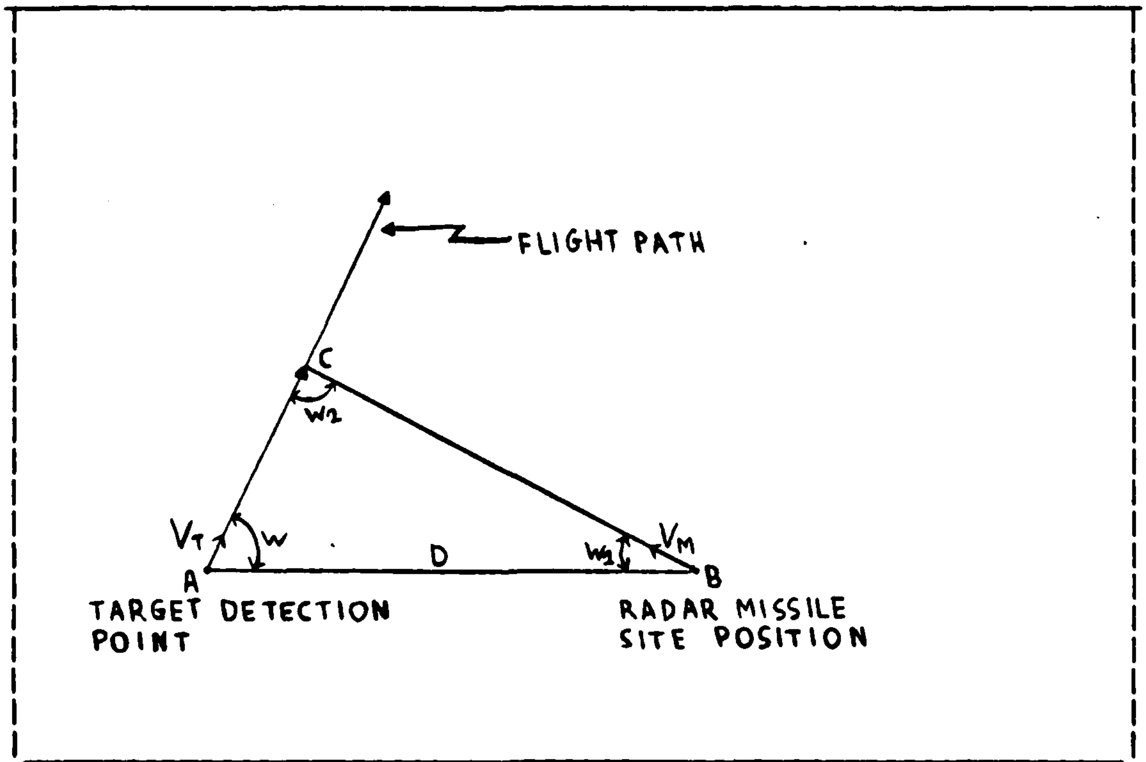

Figure 6.4 Interception Geometry

The calculation of the collision point is described as follows:

Let

W = The angle between flight path of the target AC and the radar - missile site position (X,Y).

D = Distance between the position of the target at the time t and the missile site position.

VT = The speed of the target (KNOTS/h).

VM = The speed of the missile (KNOTS/h).

T = The time the interception takes.

The interception point can be computed if the distance AC is found. To do that, the law of SINES is used:

$$\frac{SIN(W)}{BC} = \frac{SIN(W1)}{AC} \Longrightarrow \frac{SIN(W)}{SIN(W1)} = \frac{BC}{AC} \tag{1}$$

$$BC = VM * T \quad \text{and} \quad AC = VT * T \tag{2}$$

$$\text{From (1) and (2)} \Longrightarrow \frac{SIN(W)}{SIN(W1)} = \frac{VM*T}{VT*T} \Longrightarrow SIN(W1) =$$

$$\frac{VT}{VM} * SIN(W) \Longrightarrow W1 = \arcsin\left[\frac{VT}{VM} SIN(W) \right] \tag{3}$$

The three angles of one triangle sum to 180 degrees, i.e.

$$W + W1 + W2 = 180 \text{ degrees} \Longrightarrow W2 = 180 - W - W1 \tag{4}$$

and by substituting the equation (3) into (4) yields:

$$W2 = 180 - W - \arcsin\left[\frac{VT}{VM} \, SINW \right] \tag{5}$$

By using again the law of SINES, the distance AC can be found:

$$\frac{SIN(W1)}{AC} = \frac{SIN(W2)}{AB} \implies AC = \frac{AB * SIN(W1)}{SIN(W2)} = \frac{D * SIN(W1)}{SIN(W2)} \tag{6}$$

Finally by comparing the equations (3), (5) and (6) the distance AC is calculated:

$$AC = \frac{VM}{VT} * \frac{D * SIN(W)}{SIN\left[180 - W - arc\left(\frac{VT}{VM} * SIN(W)\right) \right]} \tag{7}$$

The time, that the interception takes, can be calculated by dividing the distance AC by the speed of target VT:

$$T = \frac{D}{VM} * \frac{SIN\ (W)}{SIN\left[180 - W - arc\left(\frac{VT}{VM} * SIN(W) \right) \right]} \tag{8}$$

The distance BC, the distance the missile travels, is calculated by multiplying the missile speed VM by the time T.

$$BC = T * VM \tag{9}$$

In summary, if the parameters D, W, VT and VM are known, we can find the distances that the target and the missiles travel until the collision occurs and the time at which the interception takes.

It is obvious that an interception is not always possible for the following reasons:

When the distance that the missile has to travel is greater than its maximum flight range.

When the angle W is greater or equal to 90 degrees and the VM is less or equal to VT. In this case the missile will never catch the target.

The Target Interception Model is supported by the computer work space "INTERCEPT", described in Appendix E, whose purpose is to calculate, for a given radar missile site and targets, the intercept state vector. For each time step t, the intercept state vector has the following form:

$$I(t) = (i1(t), i2(t), i3(t), \dots iN(t)) \quad \text{where:}$$

N = the number of targets generated in the entire simulation.

Ij(t) = 0, implies that a missile fired at target j during this time step will have a predicted intercept point beyond the range capability of the missile system.

Ij(t) = 1, implies that a missile fired at target j during the time step will have a predicted intercept point within the capability of the missile system for one of the reasons listed above.

All the intercept state vectors form the intercept state matrix, whose form is shown in Figure 6.5. The interception

state matrix and the time that the possible interceptions require will be used later by the air model to determine whether or not an interception is successful. It will also be used to schedule the interception as future events.

TIME STEPS ↓	TGT1		TGT2		. . .	TGTN	
	RESULT	TIME	RESULT	TIME		RESULT	TIME
1	1	10	0	0			
2	0	0	1	15			
3	1	9	1	14			
.	.	.	.	.			
.	.	.	.	.			
.	.	.	.	.			
M	1	12	0	0			

Figure 6.5 An Interception State Matrix for One Site

C. TARGET PRIORITY MODEL

Modern radar sites can track and fire on more than one target and almost all radar sites (old and modern) can detect more than one target simultaneously. In such cases, each radar site has to know the priority of target engagement.

To simulate the priority of the target, either simple or complex techniques can be used. In this air model, the following technique is employed. The priority of each target

is determined from its flight route for each time step. Analytically, the target priority model uses the following rules:

Rule 1: Two or more attacking targets

When two or more targets are penetrating the defended area at the same time, the aircraft which heads more directly towards the defenderr's critical assets, has highest priority. Figure 6.8 shows this case. The difference between the critical heading of the course and the heading of target 1 is smaller than the difference between heading critical course and heading course of target 2. Therefore target 1 has priority one and target 2 has priority two.

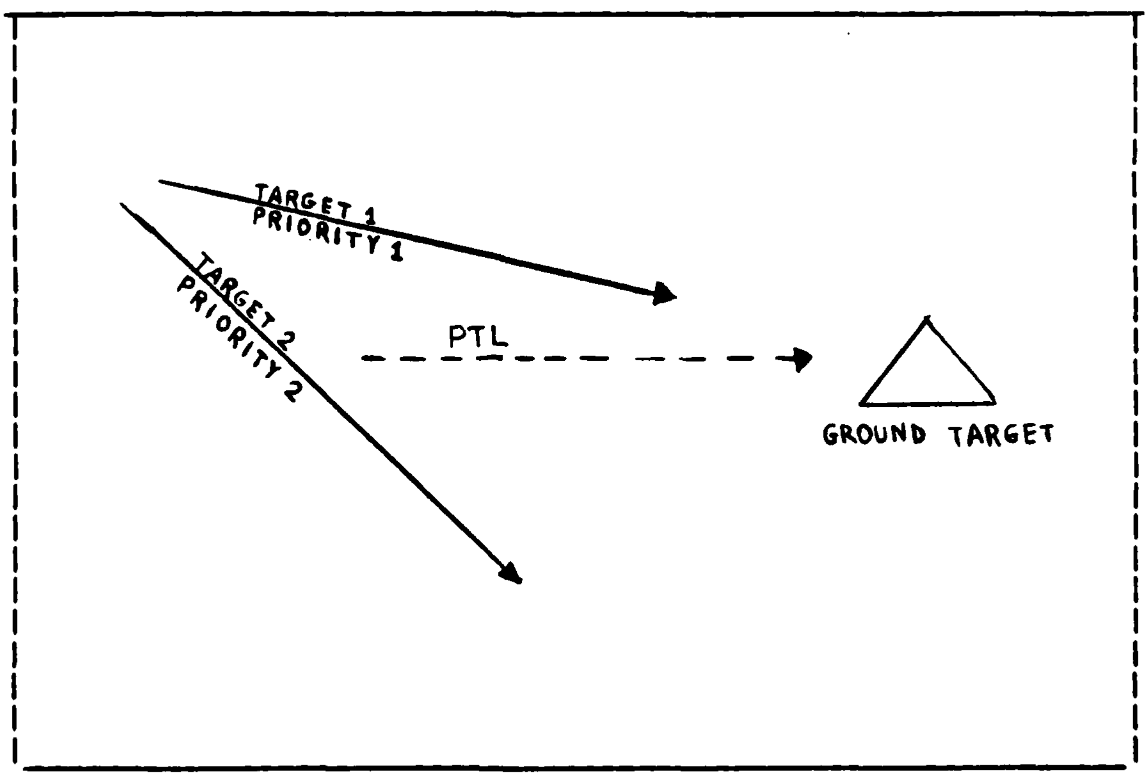

Figure 6.6 Two Attacking Targets

Rule 2: Attacking and Returning Aircraft

When the priority model simulates two targets one of which is attacking and the other is returning to its own territory, it assigns a higher priority to the first target than to the second. The reason is that the attacking targets are more dangerous than the returning ones. This case is shown in Figure 6.7. Target 1 has higher priority than target 2.

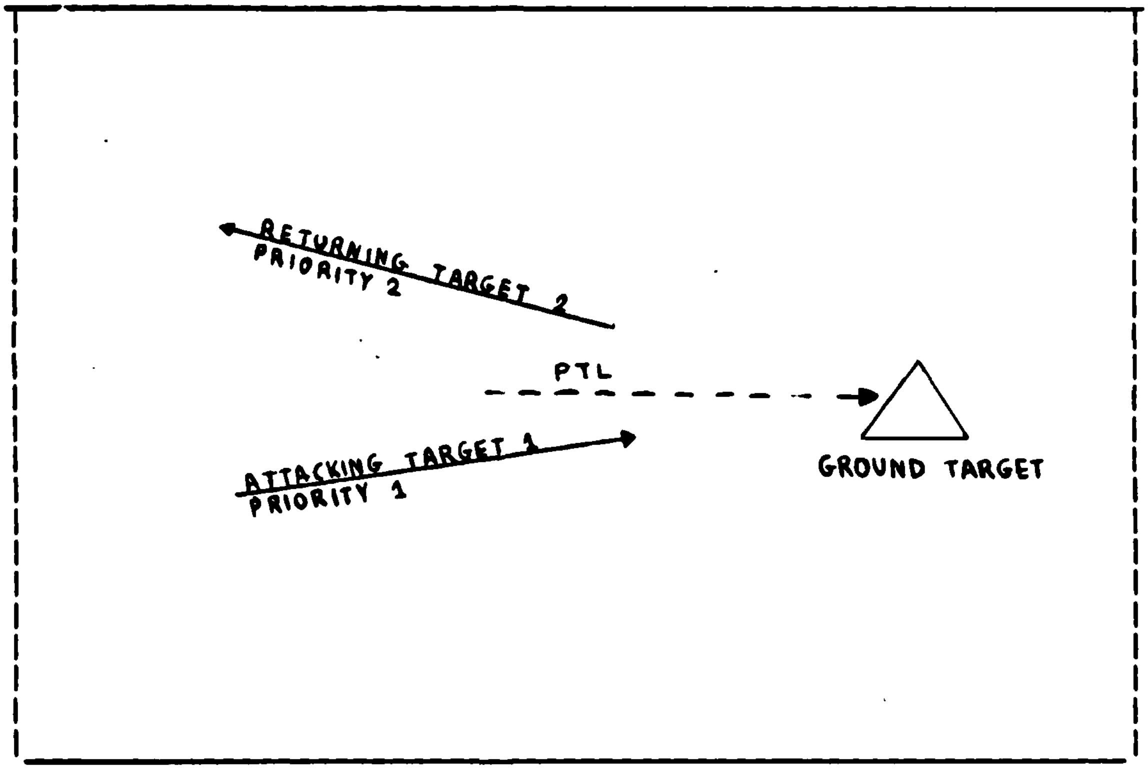

Figure 6.7 Attacking and Returning Targets

Rule 3: Two or more Returning targets

In the case of two or more returning targets, the target which heads more directly away from the defender's critical assets has the higher priority. The reason is that

the interceptor missile has less time to intercept the first target than the second one. Figure 6.8 shows this case. The difference between the heading of the critical course and the heading of target 1 is smaller than the difference between the heading of the critical course and the heading of target 2. Therefore, target 1 has priority one and target 2 has priority two.

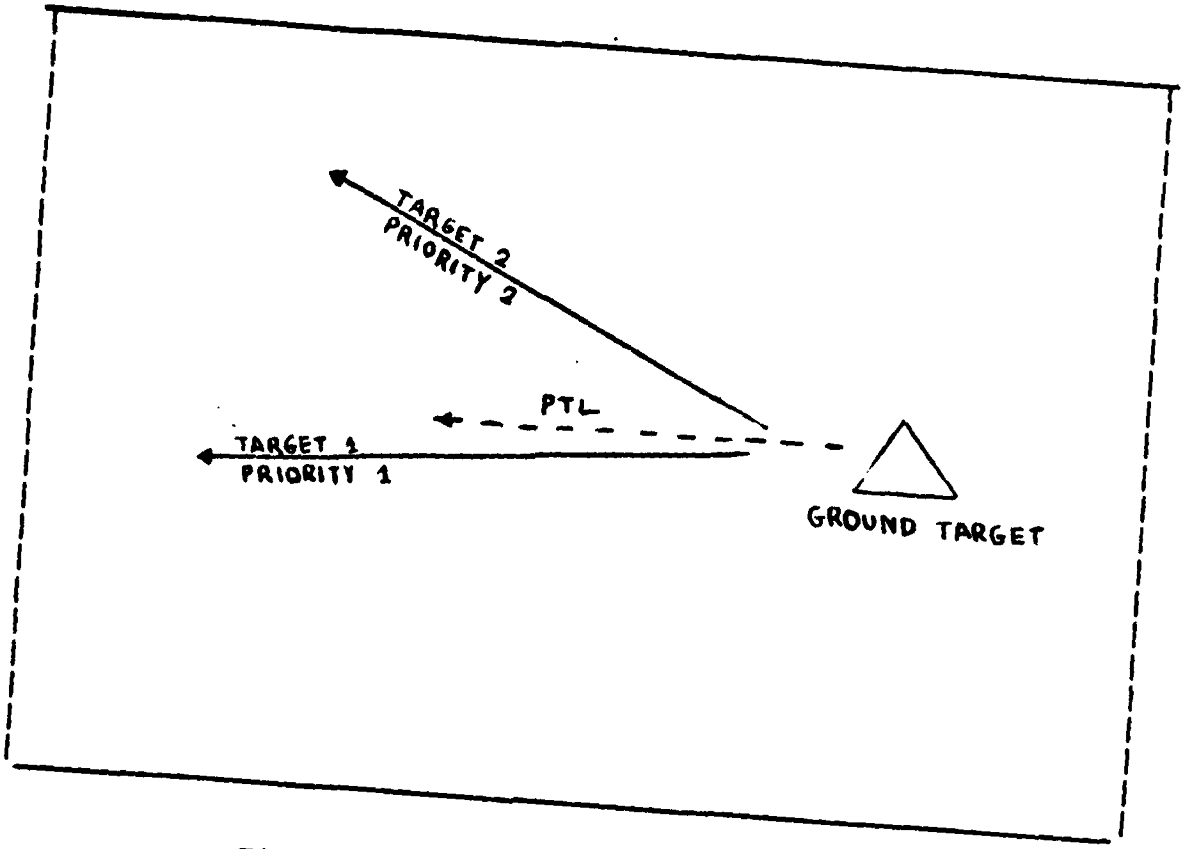

Figure 6.8 Two Returning Targets

All three rules define the prioritization state vector which has the following form:

P(t) = P1(t), P2(t), P3(t),....PN(t)

where

N = Number of targets in the entire simulation

Pi(t) = 1 when the target i has priority 1 etc.

All the priority state vectors form the priority state matrix whose form, for 5 targets, is shown in Figure 6.9. For example in time step 1, in Figure 6.9, target 4 has priority one, target 2 has priority two, target 1 has priority three and so on.

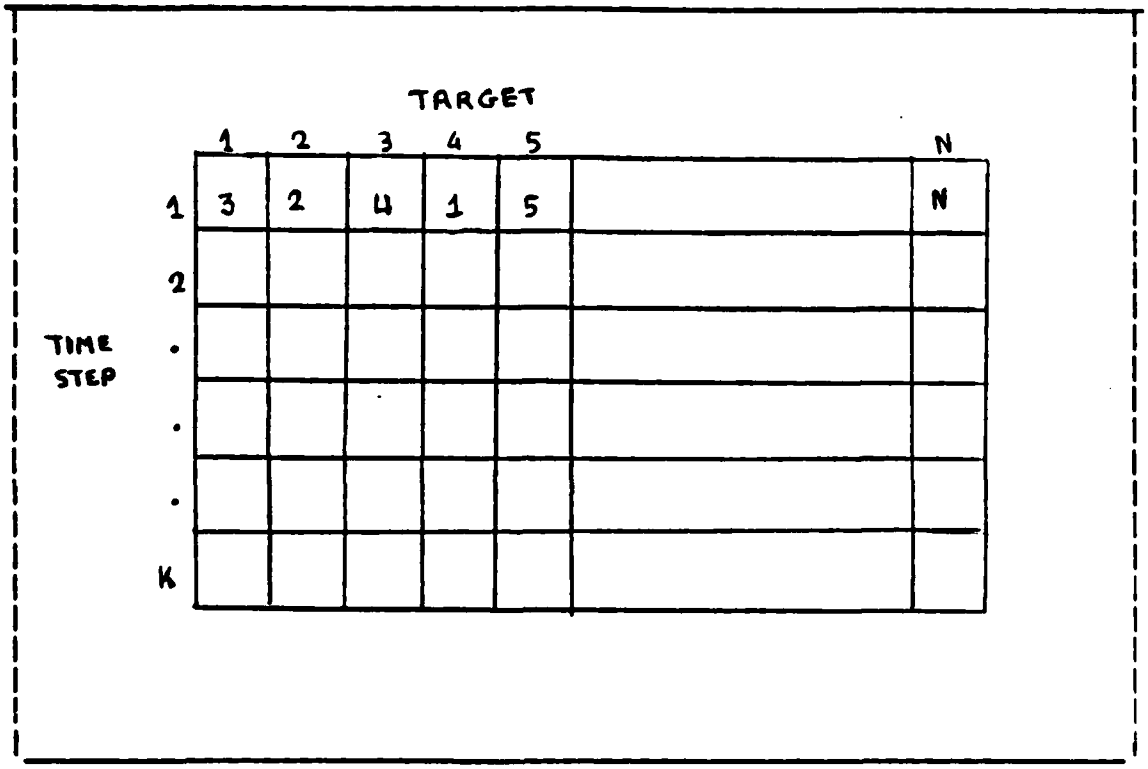

Figure 6.9 Priority State Matrix

The target priority model is supported by the "PRIORITY" computer work space described in Appendix E. The inputs of this program are the critical course of the ground target that the attacking aircraft are going to attack and the flight data of each attacking formation. The output of the

priority program will be used by the airmodel to determine the priority of each target when one radar site detects more than one target.

VII. ADDITIONAL MODELS

Chapter seven describes the following models:

A. IDENTIFICATION FRIEND OR FOE MODEL (IFF)

B. ELECTRONIC WARFARE (ECM) MODEL

C. COMMAND AND CONTROL MODEL

D. RADAR PERFORMANCE MODEL

E. PROBABILITY OF KILL MODEL

A. IDENTIFICATION FRIEND OR FOE (IFF) MODEL

1. Introduction

Another problem that a radar site commander has when a target is detected by the radar site, is to determine if a target is friend or enemy. Since this identification is impossible to obtain by optical means, both radar sites and aircraft are equipped with electronic devices which cooperate to give the identification of the aircraft.

2. Description

The IFF process, during operations, is very complicated. There are many decisions which must be made, as far as the identification of a target is concerned. For example, what must be decided if the IFF of radar site is not working? Will the target be regarded as a friend or a foe?

In this air model, the IFF process is illustrated in Figure 7.1.

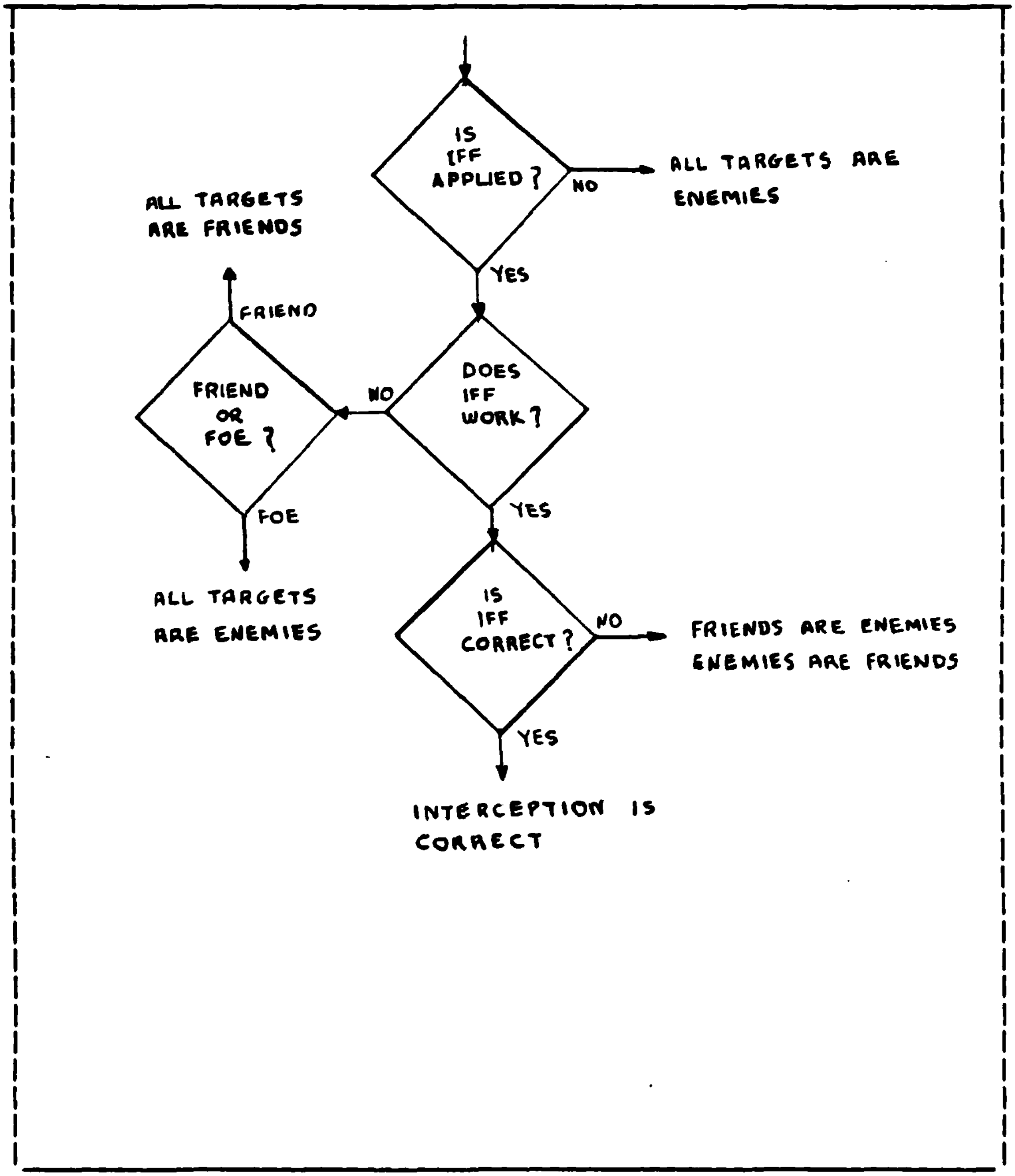

Figure 7.1 Logic Diagram of IFF Model

The above diagram is explained as:

a. Is IFF Applied? Sometimes, radar sites do not apply IFF and they consider all targets to be enemies. That

may happen, for example, during a certain period of time, when there are no friendly aircraft scheduled to fly within range of the particular radar site. In this case radar operators gain time during the interceptions, but they assume that all detected targets are enemies and they can be killed. On the other hand, if IFF is applied the next question must be answered.

b. Is IFF working? Like other electronic devices, the IFF equipment is not always working. This may happen because either the IFF equipment of the aircraft or the IFF equipment of the radar site is not responding properly. If IFF is not working, the user must decide whether to treat the target as friend or as foe. If a target is friend the radar site stops the interception process and searches for another target. If the target is enemy, the interception process continues.

c. Is IFF correct? Unfortunately, IFF systems do not always give correct results. There is a possibility that even if the target is an enemy, the IFF system will indicate that the target a is friend. On the other hand, there is a possibility that, even if the target is a friend, the IFF system will indicate that the target is an enemy. If the first case happens, there is no big problem, just one enemy aircraft will pass without being intercepted. If the second case happens, friends will kill friends and a fratricide may occur.

The air model prompts the following inputs for IFF model:

1. If IFF is applied.

2. What is the probability that IFF works.

3. What is the identification of the target if the IFF does not work (friend of foe).

4. What is the probability that the IFF gives a correct answer (given that the IFF works).

B. ECM MODEL

1. Introduction

As the technology of the antiaircraft weapons (missiles, radar guided AAA etc) has been improved, the aircraft self protection means against the antiaircraft weapons have also been improved. Today, almost all airplanes use electronic devices for antimissile purposes such as electronic countermeasure means (ECM), chaffs, flares etc. Since this airmodel deals only with radar sites which use guided missiles to destroy the aircraft, only the electronic countermeasure means (ECM) will be simulated.

2. Description

The electronic countermeasure means are electronic devices which first recognize that the formation has been detected and acquired by the enemy radar sites. Then they try, by transmitting electronic energy, to brake the acquisition and if possible to "blind" the enemy radar for as

long as the aircraft formation flies within its range. Figure 7.2 shows how a radar site detects and acquires an aircraft formation.

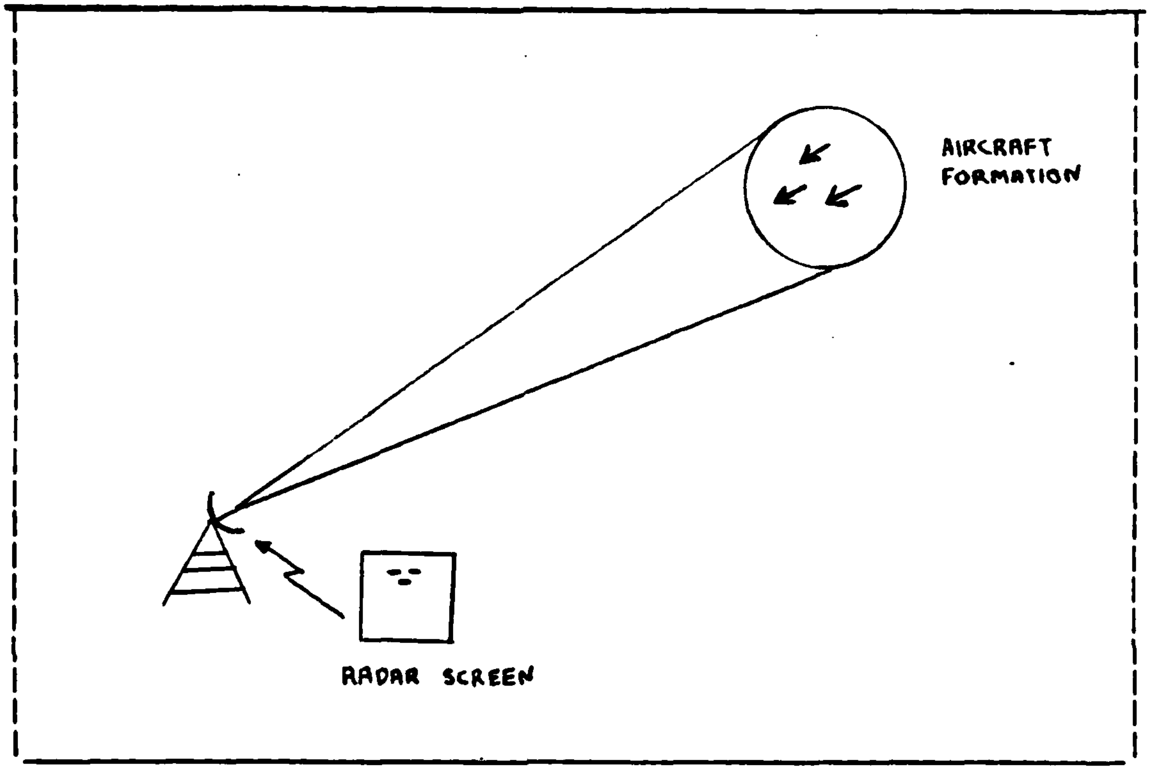

Figure 7.2 Aircraft Formation Detected by Radar Site

Modern radar sites can detect and acquire attacking formations, even if they fly in very low altitudes. On the other hand, modern aircrafts can realize both enemy radar detection and acquisition and they can, in most cases, break the lock-on if it exists or "blind" the enemy radar partially or totally. Figure 7.3 shows an aircraft formation which transmits electronic energy in order to break the radar site acquisition.

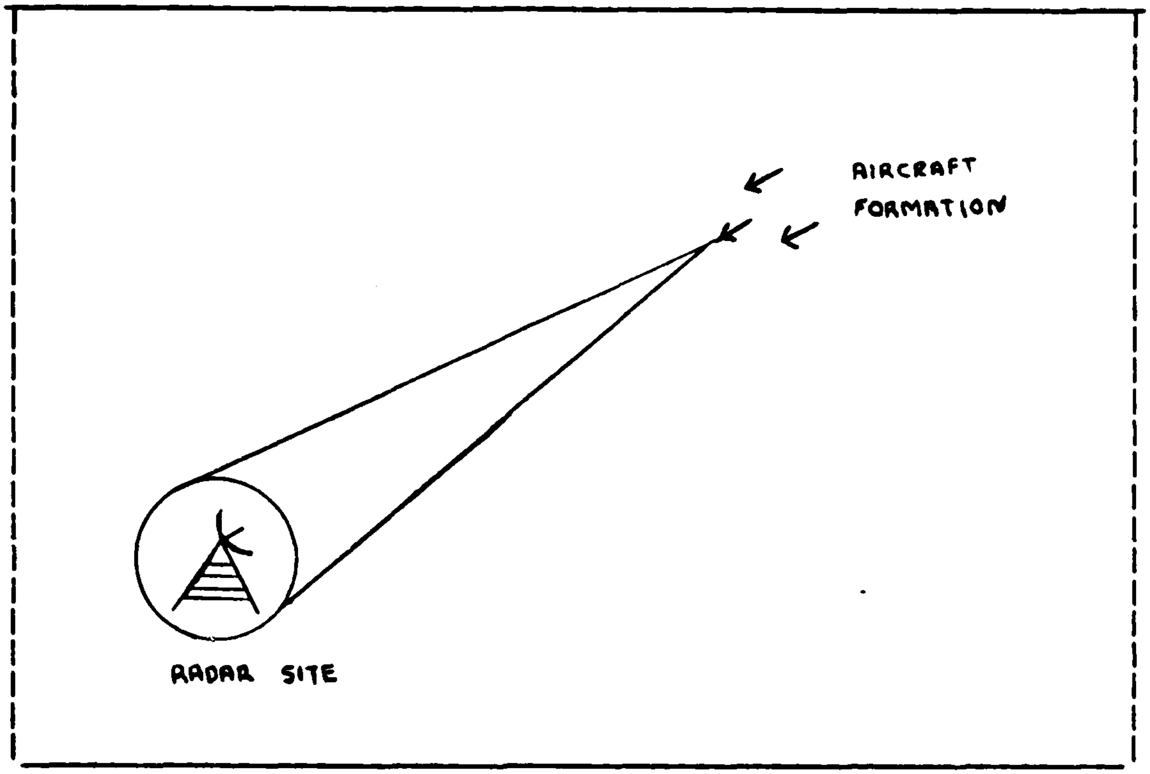

Figure 7.3 Aircraft Formation Using ECM

a. ECM Parameters

The success of the ECM employed by the aircraft formation depends on many factors but the most important are the power of the ECM device (P), the transmit angle (W) and the distance between aircraft formation and radar site (R). This is shown in Figure 7.4.

(1) Power. Like every electronic device, the ability of ECM depends on how much electronic energy is transmitted. The more energy there is, the more efficient the ECM. Unfortunately, large power ECM devices are very heavy and only special electronic aircrafts can carry them.

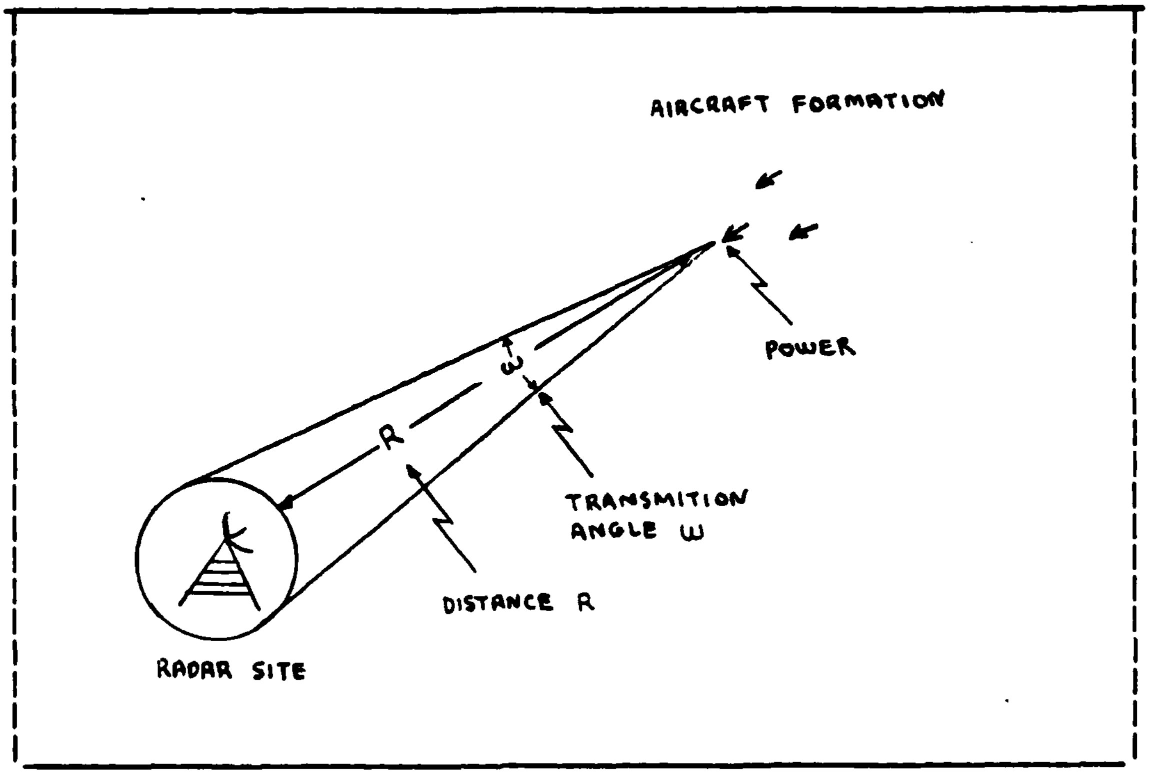

Figure 7.4 Parameters of ECM Device

Most fighter aircrafts use small or moderate power ECM and improve the ECM efficiency by narrowing the used transmitting angle w.

(2) Angle of transmiting energy. As radar sites, aircraft which apply ECM uses the angle of transmitting energy, in order to improve their ability to blind or break the acquisition of the radar site. By decreasing the angle, less electronic energy is being used to achieve the same purpose.

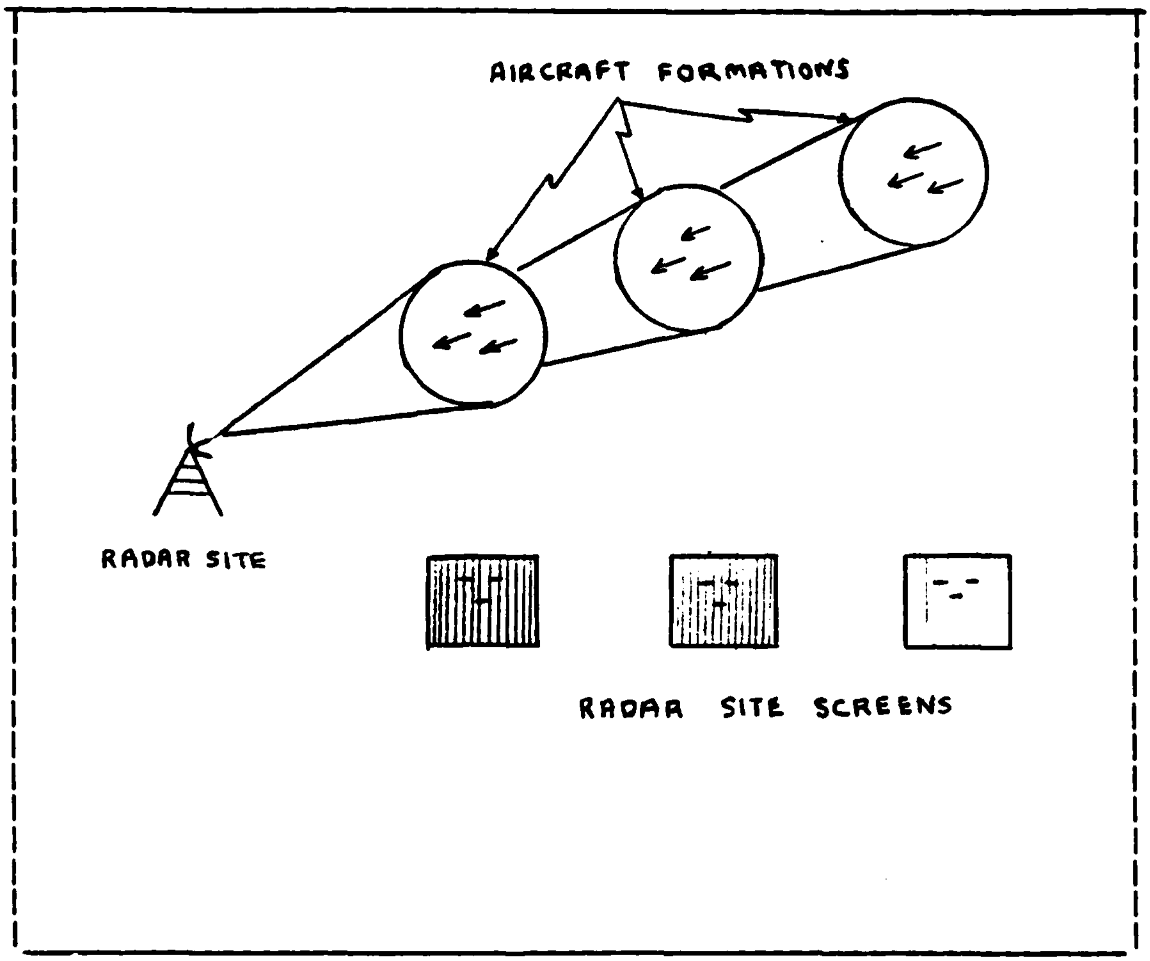

Figure 7.5 ECM Efficiency - Distance

(3) Distance between ECM and Radar Site. The distance is very important. The efficiency of ECM is inversely proportional to the distance square. How ECM efficiency changes by decreasing the distance between aircraft formation and radar site is shown in Figure 7.5.

b. ECM Function

Electronic countermeasure means can break the acquisition (lock-on) or increase the required time for identification, track, fire and target kill assessment events. To simulate the whole ECM process, two functions are needed. One function which increases the required time for the interception events and another function which changes the probability of breaking the acquisition by the radar site during the interception process.

(1) Interception Events Function. The function which increases the required time for identification, track, fire and target kill assessment events is assumed linear and has the following form:

$$\text{Time Events Matrix} = (\text{Time Events Matrix}) * \text{Increase Factor} \quad (1)$$

where time events matrix is a (N,3) matrix shown in Figure 7.6, and the increase factor is a factor that the events matrix must be multiplied with, in order that all time events be increased. For example, if the increase factor is equal to 1.5 (this value is used by the air model) the time events matrix will be increased by 50%.

	IDENT.	TRACK	FIRE	TARGET KILL ASSESSMENT
RADAR SITE 1	2	2	3	2
RADAR SITE 2	2	3	3	2
.	.	.	.	.
RADAR SITE N	3	3	4	3

Figure 7.6 Time Events Matrix

(2) Breaking Acquisition Function. When an aircraft formation is acquired by a radar site and employs ECM, there is a high probability that the radar site acquisition can be broken. The breaking acquisition function simulates this probability by using the mathematics model shown in Figure 7.7.

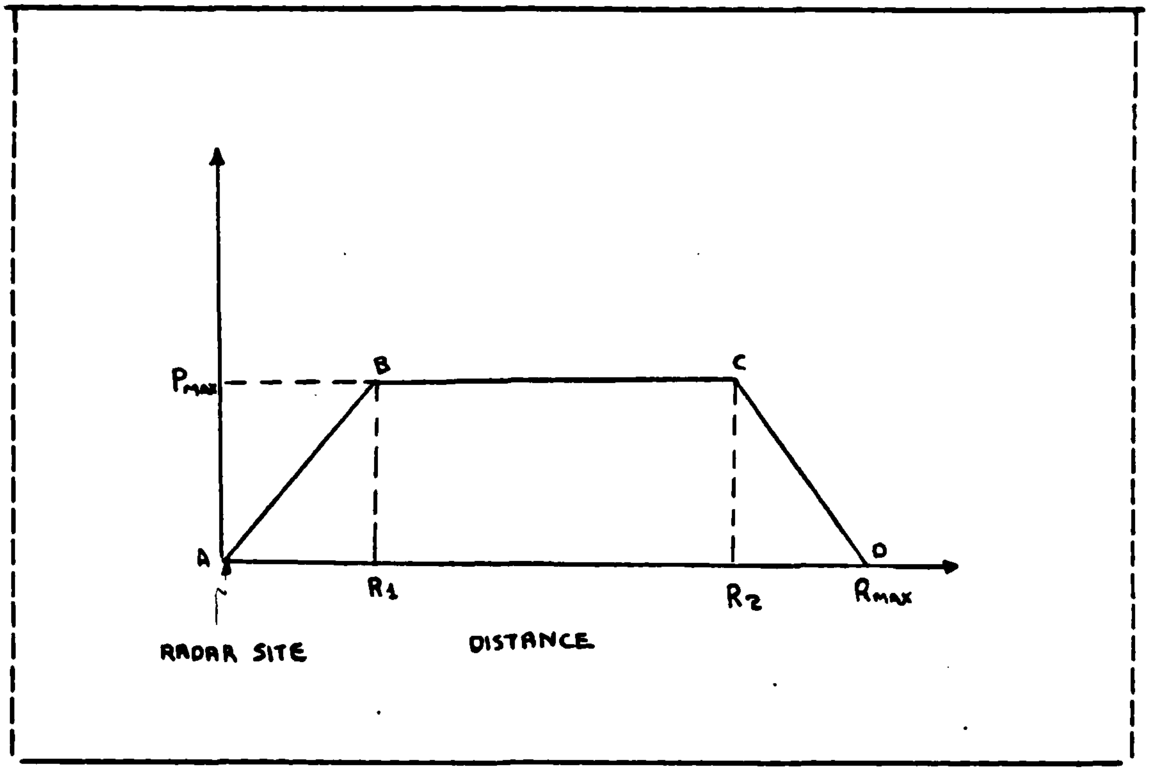

Figure 7.7 Breaking Acquisition Model

This model assumes that the probability of breaking the radar acquisition (Pr) is zero when the distance (R) between aircraft formation and radar site is greater than Rmax, increases as the distance R decreases, reaches a maximum value (Pmax) when the distance R is equal to R2, remains constant for the distance between R2 and R1 and then decreases when the distance R is less than R1. R1, R2, Rmax and Pmax are parameters of the breaking acquisition function specified by the user. The equations which gives the probability of acquisition breaking are as follows:

$$Pr = \frac{(Pm)x(R)}{R1} \qquad \text{IF} \qquad 0 < R < R1$$

$$Pr = Pm \qquad \text{IF} \qquad R1 < R < R2$$

$$Pr = \frac{(PKmax)*(R2-R)}{R2-RM} \qquad \text{IF} \qquad R2 < R < RM$$

where: R is the distance between aircraft formation and radar site.

R1, R2, Rmax, Pmax are parameters of breaking aquisition function (Figure 7.7).

Each aircraft formation has its own R1, R2, Rmax and Pmax and these data are given to the air model in matrix form as follows:

	R1	R2	Rm	Pmax
a/c formation 1	5	30	80	0.7
a/c formation 2	5	40	70	0.5
a/c formation 3	0	0	0	0
.	.	.	.	.
a/c formation N	5	20	50	0.5

The first column is the R1 distance for a/c formations.
The second column is the R2 distance for a/c formations.
The third column is the Rmax distance for a/c formations.
The fourth column is the Pmax for a/c formations.
The fifth column is the probability than ECM works.
The third row is zero because the third a/c formation does not employ ECM.

The logic diagram for the ECM process is shown in Figure 7.8.

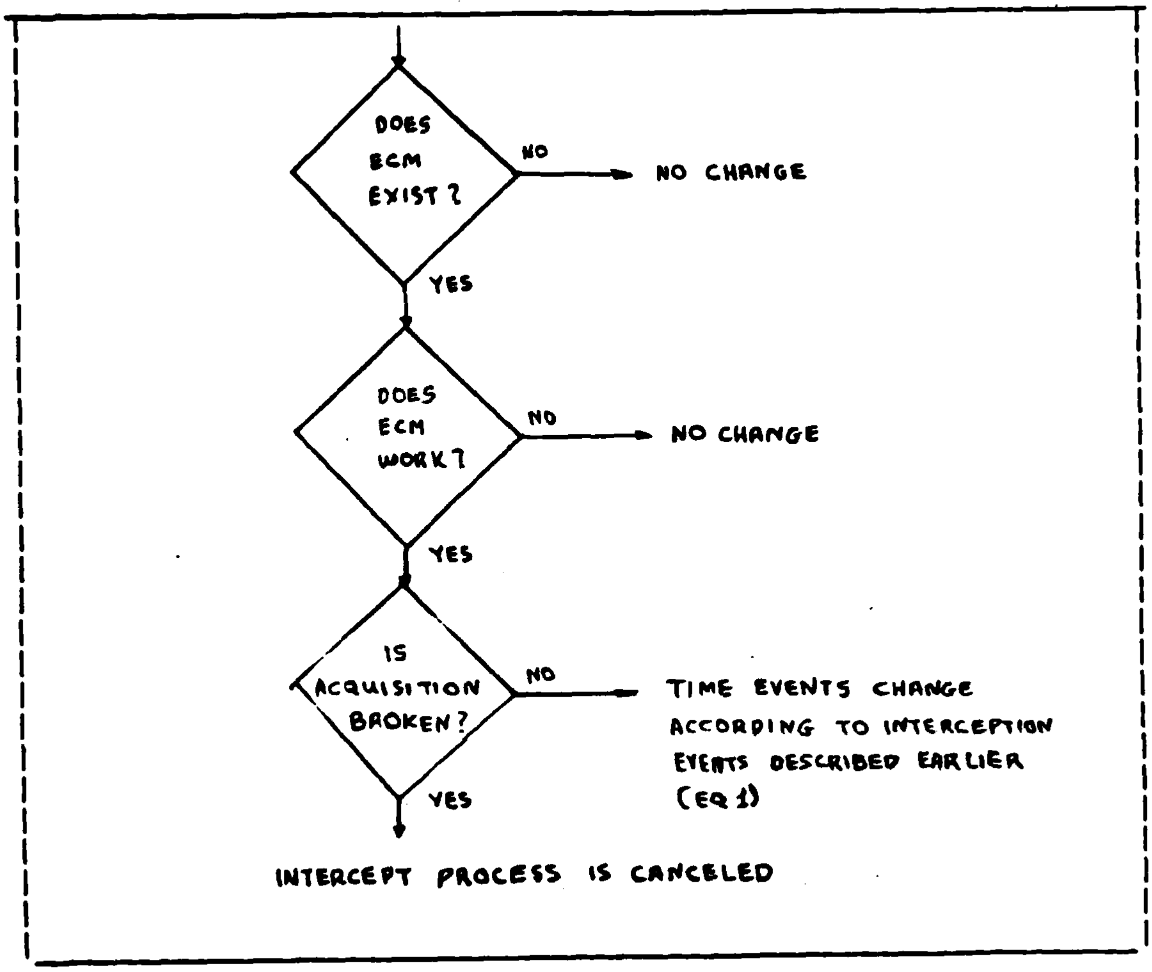

Figure 7.8 ECM Process Logic Diagram

The algorithm of the ECM process follows the steps:

Step 1: Does the aircraft formation apply ECM?

If NO: No changes to interception time events.

If YES: Go to step 2.

Step 2: Does ECM work?

If NO: No changes to interception time events.

If YES: Go to step 3.

Step 3: Is radar acquisition broken?

If NO: Identification, track, fire and target assessment time events will increase according to equation (1).

If YES: Further intercept process is cancelled and target goes again for identification.

C. COMMAND AND CONTROL MODEL

1. Introduction

When two or more radar sites cooperate to defend an area, a centralized command and control organization must exist to control all the radar sites. For example, if there are more than two targets flying over this area, the centralized organization will decide what target radar site one will engage, what target radar site two will engage and so on. In this way, more targets will be destroyed because each radar site will engage only its own targets.

2. Description

Since a complex command and control model is very difficult to simulate, the airmodel uses the following simple algorithm: No target will be engaged by more than one radar site. That means that when a particular target is engaged by a radar site, no other radar site is allowed to engage it until the target is released (not destroyed) by the original radar site. By using this algorithm there is not possibility for two radar sites to destroy the same target. This rule

can be revised and the aircraft formation can be engaged by more than one radar site if the number of aircraft in the formation is greater than a certain number N. This number is prompted by the air model and it must be entered by the user. For example, if N = 3 and the aircraft formation has five aircraft, then this formation can be engaged by more than one radar site until only 3 aircraft remain in this formation.

Figure 7.9 shows the logic diagram of command and control model.

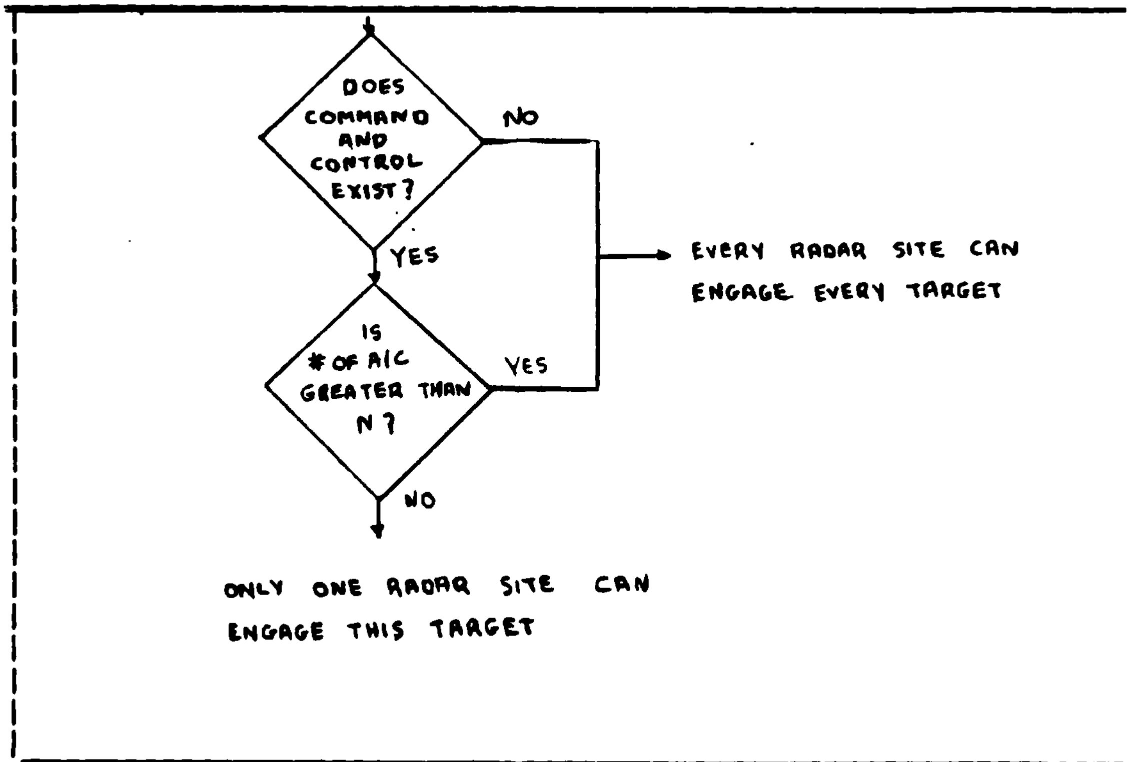

Figure 7.9 Logic Diagram of Command and Control Model

The algorithm of the command and control model follows these steps:

Step 1: Does command and control model exist?

If NO: Every radar site can engage this target.

If YES: Go to step 2.

Step 2: Is the number of aircraft less than N (user input)?

If NO: Every radar site can engage this target.

If YES: Only one radar site is allowed to engage this target.

D. RADAR PERFORMANCE MODEL

1. Introduction

The performance of the radar sites depends on many factors such as age of radar site, experience of operators, weather conditions, and enemy ECM. In addition, there is a possibility that the radar site will be partially or totally destroyed during the operations.

2. Description

The air model uses a simple radar performance model. It aggregates all factors which effect the performance of radar site to one factor called "performance". This factor is prompted by the airmodel and it takes one of the two values that follow:

'1' if the user prefers the radar site to work in full performance, and

'Ø' if the user prefers the radar site to work in limited performance.

Figure 7.1Ø shows the logical diagram of the radar performance model:

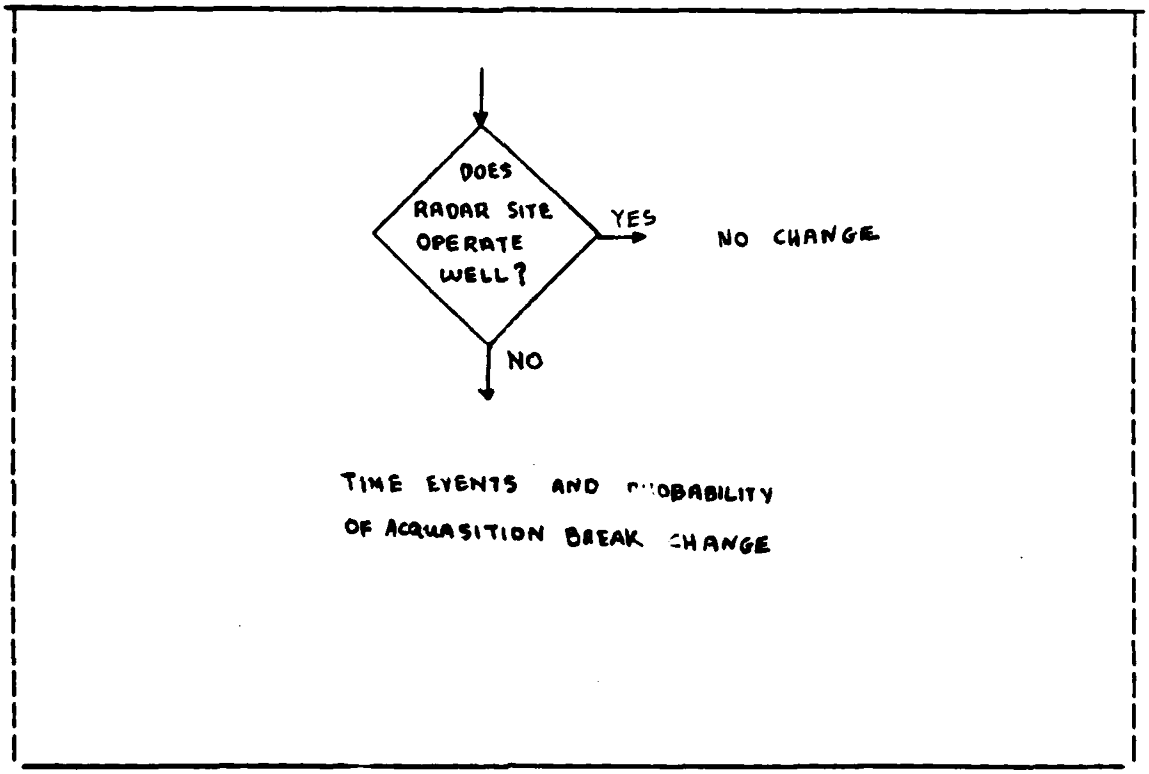

Figure 7.1Ø Logic Diagram of Radar Site's Performance Model

If radar sites operate in full performance (performance value is 1) there is no change to airmodel. If radar sites work in limited performance (performance value is Ø) the identification, track, fire and target assessment time are increased by a factor input by the user. The probability

that a radar site acquisition will be broken due to ECM can also be increased by a factor determined by the user. If the radar site operates in limited performance situation, the time to identify, track, fire and assess a target kill increases and the chance that a target acquisition will be broken is also more likely.

E. PROBABILITY OF KILL MODEL

1. Introduction

Calculation of probability of killing (PK) an aircraft by using a guided missile is very important, but unfortunately, extremely difficult to calculate.

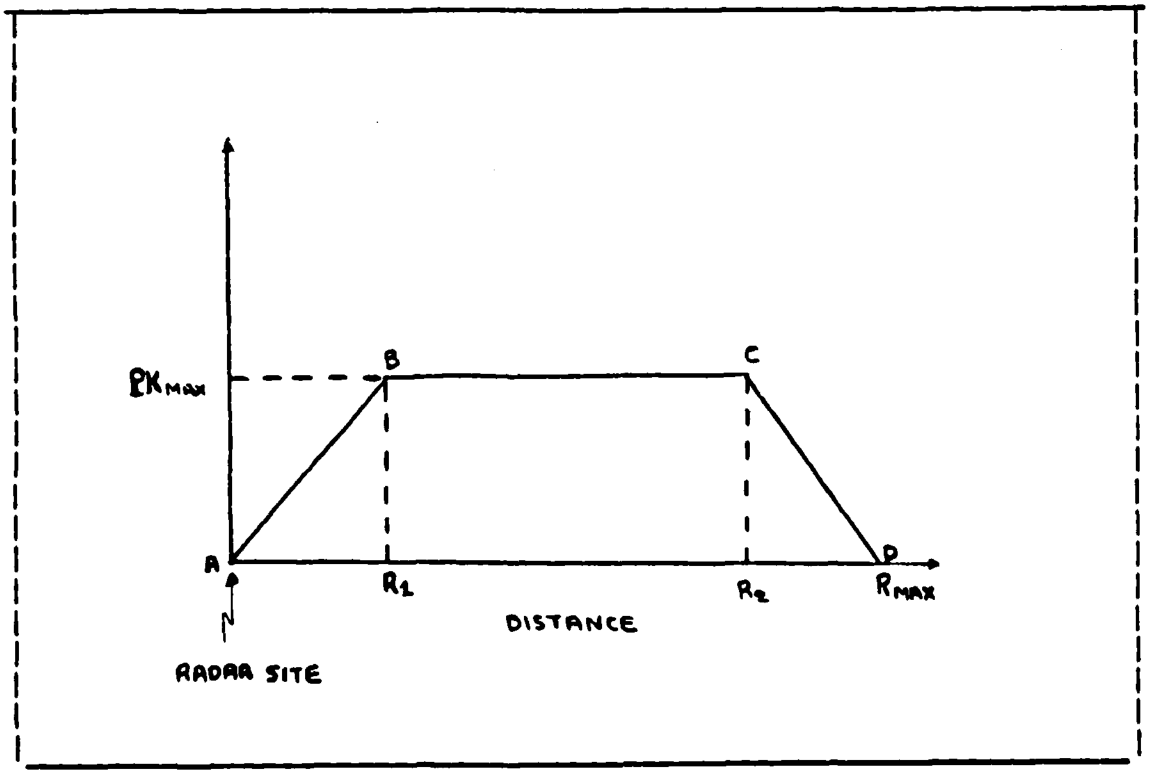

Figure 7.11 Probability of Kill Model

The problem is that the probability of kill depends on so many factors, known and unknown, that it is essentially impossible to create a relatively simple model to estimate it using all the factors.

2. Description

The airmodel uses a simple, but quite reasonable model to estimate the PK. It assumes that the probability changes Linearly as the range between the a/c and the radar site changes. Figure 7.11 shows how the PK changes relatively to R.

The PK is zero when the distance (R) between aircraft formation and radar site is greater than the maximum range (Rmax) of missile that this particular radar site uses. The propability of kill increases as R decreases (aircraft approaches the radar site) reaching the maximum value (PKmax) at R2, it stays constant for the distances between R2 and R1 and then decreases when the distance R is less than the distance R1. R1, R2, Rmax and PKmax are values prompted by the airmodel.

The equation used to calculate the PK, are the same as in the ECM model, is:

$$PK = \frac{(PK) \times (R)}{R1} \qquad \text{IF} \qquad 0 < R < R1$$

$$PK = PKmax \qquad \text{IF} \qquad R1 < R < R2$$

$$PK = \frac{(PKmax) \times (R2-R)}{R2-Rmax} \qquad \text{IF} \qquad R2 < R < Rmax$$

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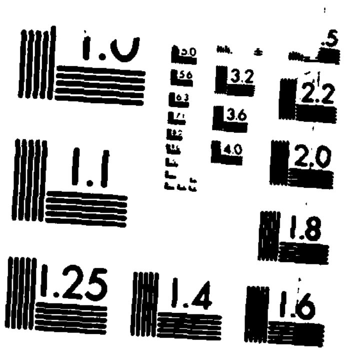

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where: R = the distance between aircraft target and radar site.

R1, R2, Rmax, Pmax are parameters of the probability of kill function and must be entered in the air model by the user for each radar site in matrix form as follows:

	R1	R2	Rmax	PKmax
Radar Site 1	5	15	20	0.50
Radar Site 2	7	35	40	0.55
.	.	.	.	.
Radar Site N	10	50	55	0.40

The first column is the R1 distance for each radar site.
The second column is the R2 distance for each radar site.
The third column is the Rmax distance for each radar site.
The fourth column is the PKmax for each radar site.

VIII. COMPUTER PROGRAM "AIRMODEL"

Chapter VIII describes the "AIRMODEL" computer work space. It defines the functions, inputs, and outputs of the program.

A. INTRODUCTION

In the previous chapters, the pre-processing models were described in detail. All these models were deterministic because the outputs are the same, given the same inputs. These models calculate all the data that the "AIRMODEL" work space needs to run. The purpose of "AIRMODEL" is to calculate the attrition rate of the attacking aircraft formation by using the data given by the models described in Chapter II through VII. This program simulates the aircraft formation engagement sequence by the radar sites. An air defense radar site follows a well defined engagement sequence as it attempts to destroy enemy aircraft. The steps of the sequence are:

Step 1: Detection. The system/operator observes the presense of an aircraft formation on the radar screen in the assigned airspace.

Step 2: Identification. The operator identifies the target as friend or foe.

Step 3: Track. The site tracking radars obtain radar lock on the target.

Step 4: Fire. The site launches a missile attempting to destroy the target.

Step 5: Intercept. The missile arrives at a predicted point in space. This point is assumed to be the location of the collision of the missile and the target.

Step 6: Aircraft Kill Assessment. The system/operator decides if target destruction has been achieved.

These steps are illustrated in Figure 8.1.

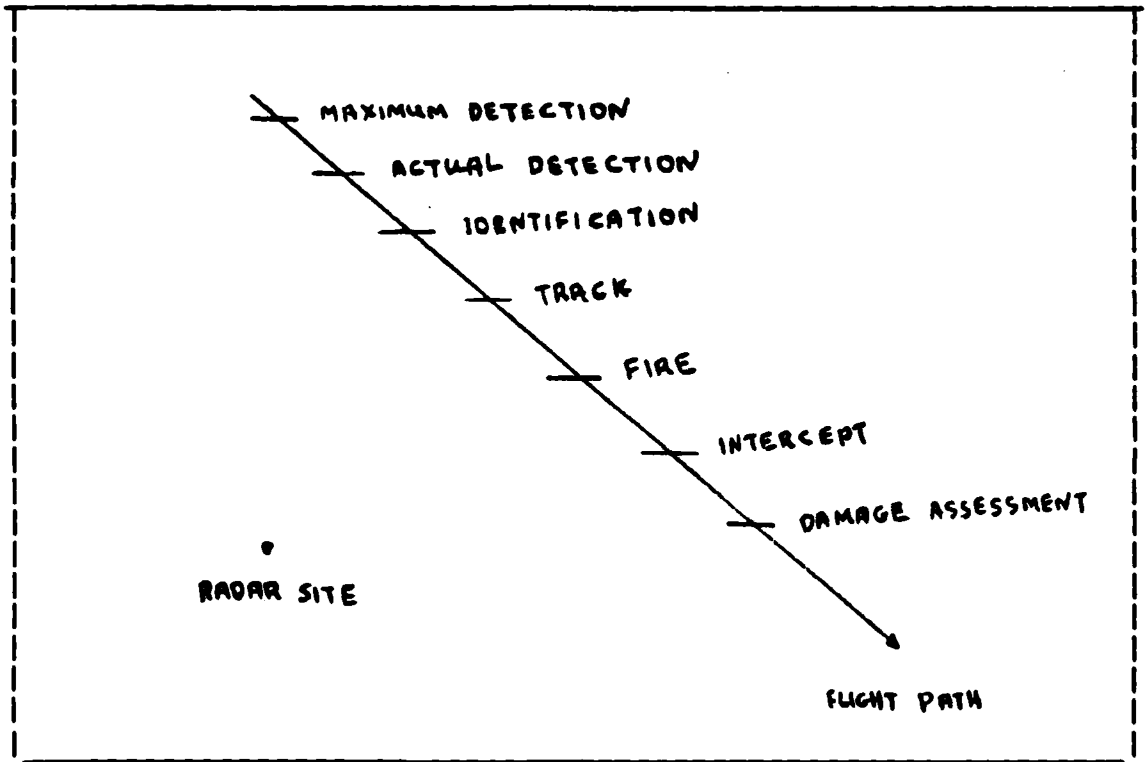

Figure 8.1 The Engagement Sequence

If the target leaves radar surveillance (either acquisition or tracking), the sequence is terminated. When

the target returns to the site detection envelop, it is considered to be a new acquisition.

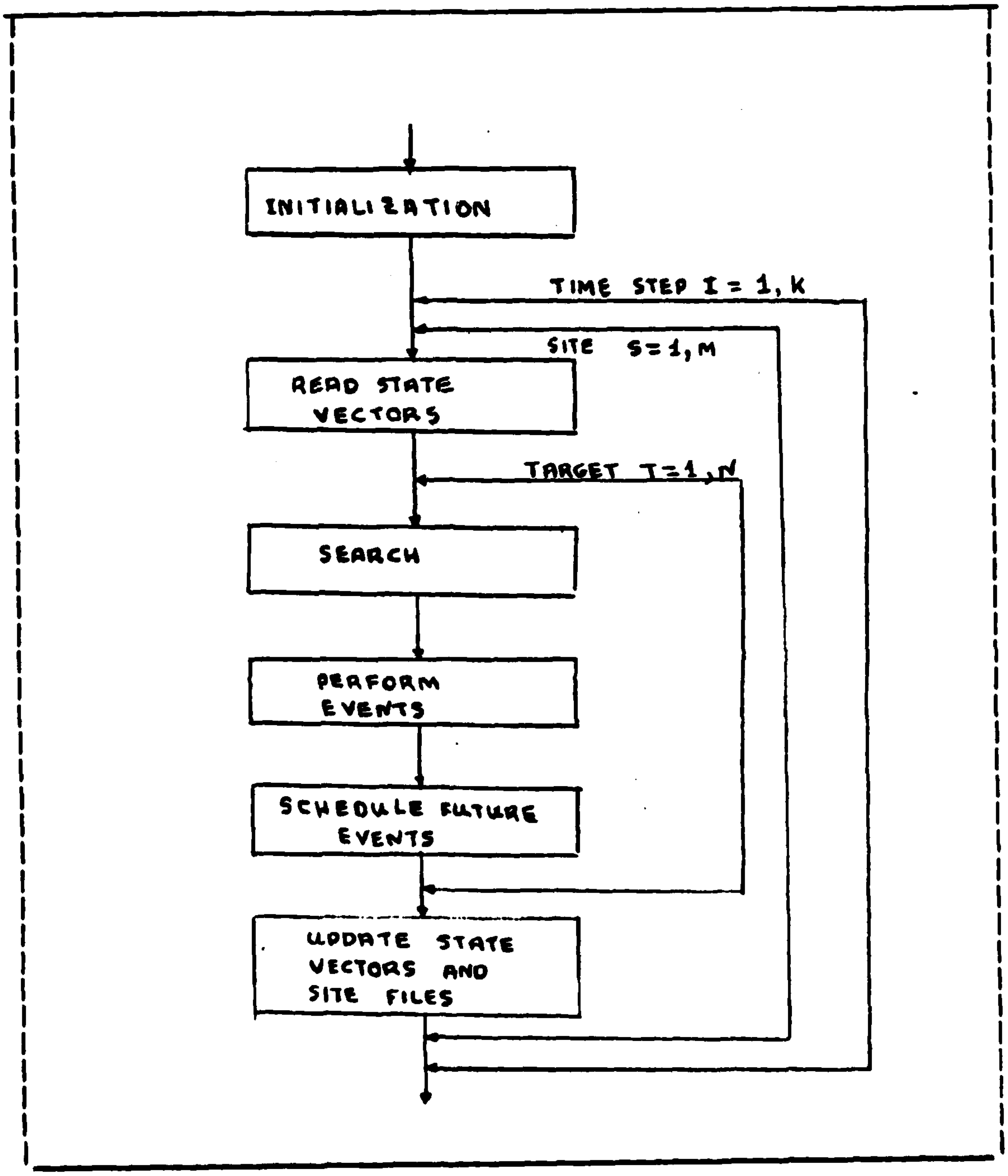

Figure 8.2 Airmodel Flow Chart

The time delays associated with each step of the sequence are defined as follows:

Td = time between maximum possible detection and actual detection.

Tid = time between actual detection and identification.

Tt = time between identification and track.

Tf = time between track and fire.

Ti = time between fire and interception.

Ta = time between intercept and assessment of the intercept.

The flow chart of the "AIRMODEL" is shown in Figure 8.2.

B. DESCRIPTION

The work space "AIRMODEL" consists of the following computer functions:

1. MAIN
2. SITE
3. IDIF
4. TRACK
5. FIRE
6. INTER
7. ASSES
8. PKILL
9. RANDOM

1. Main

a. Header

The header of the "MAIN" program is ""MAIN" and the computer program is listed in Appendix F.

b. Purpose

The purpose of the main computer function is to prompt all the inputs from the user and to call the site function in order to calculate the attrition rate of the aircraft formations.

c. Input

The "MAIN" computer program prompts the following inputs:

1. RL: The seed for the random number function. This seed is needed to generate random variable inputs. If the main program runs the same data twice, the same sequence of the output will be produced unless the seed is changed.

2. Times: The number of times that the program will run.

3. NSITES: The number of radar sites in the particular scenario.

4. DS2: The detection matrix of each radar site, given by the "FDETECT" computer work space. The "MAIN" program will prompt the entering of the detection matrix based on the number of radar sites.

5. IS2: The interception matrix of each radar site, given by the "INTERCEPT" computer work space. The "MAIN" program will prompt the entering of the interception matrix based on the number of radar sites.

6. TGT: The number of aircraft that each formation has. If the number of aircraft is zero during the

simulation, the aircraft formation is deleted from the simulation process. The TGT input is a vector whose number of elements must be equal to the number of aircraft formations (each element equal to the number of a/c).

7. CAP2: The number of aircraft that each radar site can engage. If a particular radar site has engaged its maximum number of aircraft, it is considered to be satutated and is not allowed to engage more targets. The CAP2 input is a vector whose number of elements must equal the number of radar sites (each element for each radar site).

8. MCAP2: The number of missiles that each radar site possesses. If a particular site has launched all its missiles, then it is deleted from the simulation process. The input MCAP2 is a vector whose number of elements must be equal to the number of radar sites (each element for each radar site).

9. PKM: The probability of kill matrix, given by the "PROBABILITY OF KILL" model.

10. IFF: The IFF input takes one of two values as follows:

1 = IFF is applied in the simulation process.

0 = IFF is not applied.

If IFF is not applied, the "MAIN" program assumes that a detected target is always friend.

11. IFFWORK: The probability that the IFF works

12. IFFFOE: The IFFFOE input takes one of two values as follows:

1 = a target is friend if IFF does not work.

Ø = a target is foe if IFF does not work.

13. IFFCOR: The probability that IFF is correct given that it works.

14. ECM: The electronic countermeasure matrix, given by the "ECM" model.

15. CMD: The input CMD takes one of two values as follows:

1 = command and control model is applied.

Ø = command and control model in not applied.

16. PR: The priority matrix, given by "THE PRIORITY" model.

17. AUTO: The condition which determines whether the radar sites operate autonomusly, given that command and model is applied.

18. WTH: The input WTH takes one of two values as follows:

1 = radar site operation is normal.

Ø = radar site operation is degraded.

19. LBR: The factor describing the increase in acquisition time, given that the operation of the radar sites is degraded.

2Ø. ETSF: The factor describing the increase in firing time given that the operation of radar sites is degraded.

21. TSTEP1: The (N,4) event time steps matrix. The columns of the TSTEP1 matrix are the required time for identification, track, fire and target damage assessment. The number of rows (N) is the number of radar sites.

d. Output

The "MAIN" program gives the following outputs:

1. Summary of the User Scenario.

2. Attrition Matrix in details. The form of the attrition matrix is as follows:

MISSILE SITE:	1	1	2	2	1	2	2	1
TIME STEP:	10	32	45	102	105	105	14	250
NUMBER OF TARGETS KILLED:	1	3	2	3	1	1	2	3

The first row consists of the number of the radar sites which have achieved a target kill. The second row documents the time steps. The third row consists of the numbers of target kills. For example, the first column means that the first radar site destroyed one aircraft from formation one in time step ten.

3. Remaining missiles for each site.

4. The number of targets which are destroyed but not assessed by the radar site. In some cases, it is possible to intercept a target without receiving clear indications of destruction.

5. The number of target kills per aircraft formation.

2. Site

a. Header

The header of "SITE" function is "SS SITE I" and the computer program is listed in Appendix F.

b. Purpose

The function "SITE" combines the database and the other functions used by the work space "AIRMODEL" to calculate the attrition rate of the attacking aircraft formations against ground targets. This function is called by the main program once for each radar site for each time step.

c. Input

1. The left argument (SS) is the number of the radar site.

2. The right argument (I) is the time step.

d. Output

The function SITE does not provide any output, instead it calls the IDIF, TRACK, FIRE, INTER, ASSES, RANDOM and PKILL functions in order to schedule future events and calculate the attrition rate.

3. IDIF

a. Header

The header of the "IDIF" function is "ID <- ISIT IDIF R"; the computer program is listed in Appendix F.

b. **Purpose**

This function is called by the program "SITE" to perform the identification of the targets.

c. Input

1. The left argument (ISITE) is a vector whose first element is the number of the radar site and whose second is the time step.

2. The right argument (R) is the number of the target.

d. Output

The ouput is the future identification event.

4. Track

a. Header

The header of the function "TRACK" is "TT <- ISITE TRACK T"; the computer program is listed in Appendix F.

b. Purpose

The function TRACK is used by the SITE program to perform the track target event.

c. Input

1. The left argument (ISITE) is a vector, whose first element is the radar site number and whose second is the time step.

2. The right argument (T) is the number of the target.

d. Output

The output is the future track event.

5. <u>Fire</u>

a. Header

The header of the function "FIRE" is "FR <- ISITE FIRE F"; the computer program is listed in Appendix F.

b. Purpose

The function FIRE is called by the SITE program to perform the missile fire event.

c. Input

1. The left argument (ISITE) is a vector, whose first element is the radar site number and whose second is the time step.

2. The right argument (F) is the number of the target.

d. Output

The output is the future missile Fire event.

6. <u>INTER</u>

a. Header

The header of the function "INTER" is "INT <- ISITE INTER IN"; the computer program is listed in Appendix F.

b. Purpose

This function is called by the SITE program to perform the interception of the target.

c. Input

1. The left argument (ISITE) is a vector whose first argument is the radar site number and whose second is the time step.

2. The right argument (IN) is the number of the target.

d. Output

1. The time required for interception.

2. The distance that the target flies until it is intercepted.

3. The distance that the interceptor flies until the interception is performed.

4. The future target interception event.

7. ASSESS

a. Header

The header of the function "ASSES" is "AM <- ISITE ASSWS AS"; the computer program is listed in Appendix F.

b. Purpose

This function is called by the SITE program to perform the target damage assessment event.

c. Input

1. The left argument (ISITE) is a vector whose first element is the radar site number and whose second is the time step.

2. The right argument (AS) is the number of the target.

d. Output

The output is the time required to assess target damage. This is used to schedule the assessment future event.

8. PKILL

a. Header

The header of the function "PKILL" is "PK <- PKM PKILL R"; the computer program is listed in Appendix F.

b. Purpose

This function is called by the SITE program to calculate the probability of kill for each radar site and the effectiveness of ECM.

c. Input

1. The first argument (PKM) is the PK of the ECM matrix given by the Probability of Killing model and ECM model respectively.

2. The second argument (R) is a two element vector whose first element is the number of the target and whose second is the distance between the radar site and the target.

d. Output

1. The probability that a missile, launched by a radar site, will kill an aircraft.

2. The probability that the acquisition achieved by a radar site, will cease because of electronic countermeasures.

9. RANDOM

a. Header

The header of the function "RANDOM" is "RN <- RANDOM"; the computer program is listed in Appendix F.

b. Purpose

This function is called by the SITE program to generate a uniform random variable between zero and one.

c. Input

None.

d. Output

The output is a random number used to determine probabilities when a stochastic output is required.

IX. SIMULATION OF A PARTICULAR SCENARIO

A. INTRODUCTION

The technique of simulating aircraft attacks against a ground target and their interception by a missile site was described in Chapter II through VIII. In this chapter, a particular scenario is described and simulated with various combinations of inputs to calculate aircraft attrition. It also summarizes all the steps which must be followed to simulate the scenario and to calculate the aircraft attrition rate. Furthermore, the output data given by the airmodel using this particular scenario, will be analyzed and subjected to a sensitivity analysis of critical variables.

B. DESCRIPTION OF THE SCENARIO

The particular scenario used for simulation is shown in Figure 9.1.

1. Map

The map used for the scenario design is an Air Force map. It is used by pilots to plan aircraft routes for specific missions. The map scale is 1:500,000 and has sufficient contour lines to read the terrain altitudes and to plan the aircraft routes so as to take advantage of terrain masking. A 162 NM by 120 NM area is chosen to represent the enemy country which the attacking formations will fly over.

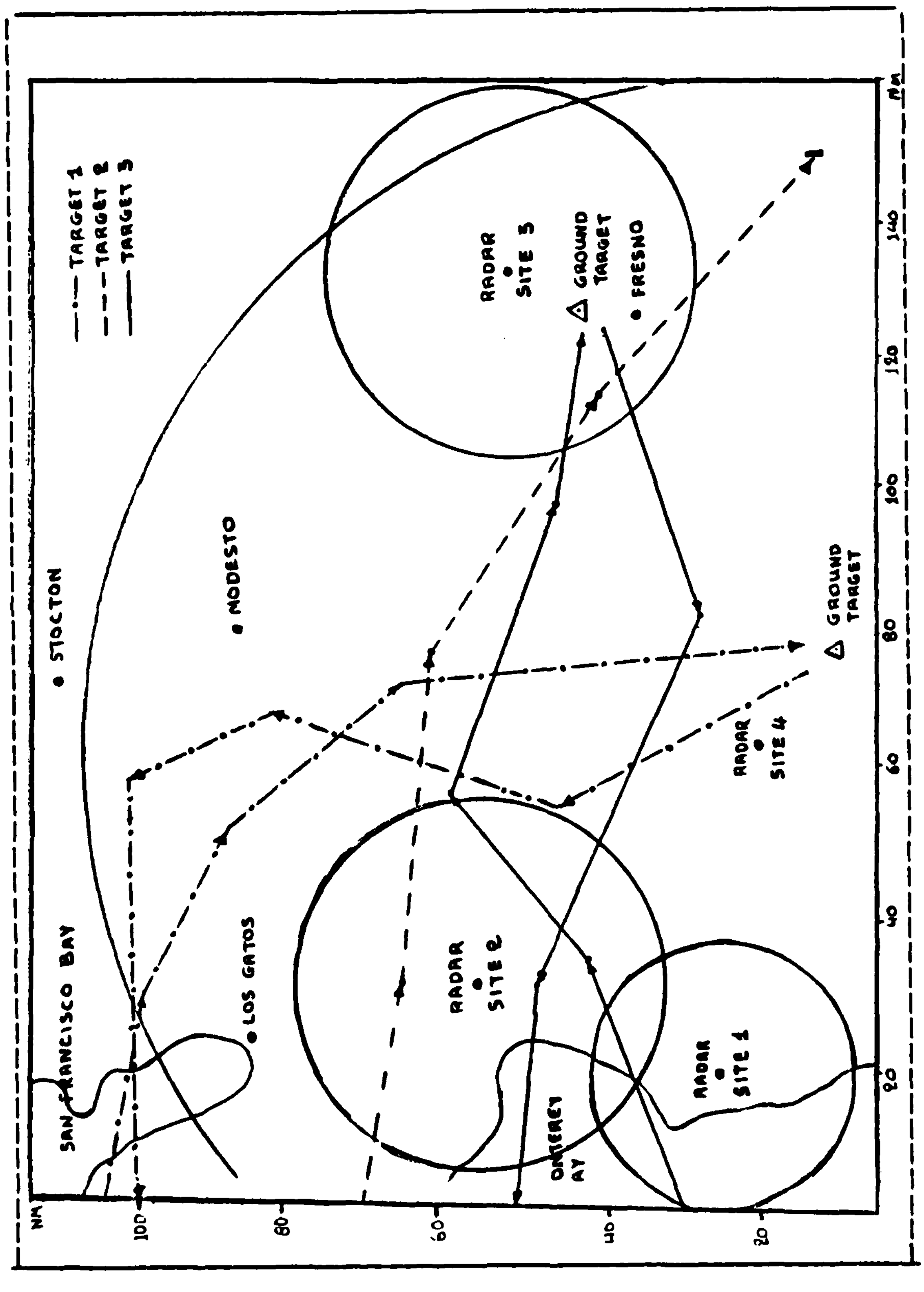

Figure 9.1 Scenario

The area is divided into grid squares. The time steps chosen for this simulation are 10 seconds.

2. Aircraft Formations

There are three aircraft formations simulated in this particular scenario.

a. Aircraft Formation 1 (Target 1)

(1) Type. The aircraft formation 1 is an enemy formation and it consists of 9 bomber aircraft.

(2) Purpose. The mission of the formation is to attack an airport whose coordinates are X = 98 NM and Y = 9 NM inland. This target will fly over the NIKE radar site.

(3) Initial point and Start Time. Formation 1 enters the enemy terrain at X = 0 NM, Y = 111 NM point and at time zero. (This is the first target entering the simulation).

(4) Flight Data. The flight routes of formation 1 consist of eight straight lines and the flight data of each flight route are listed below:

Route	Course (degrees)	Length (NM)	Speed (knots)	Altitude (feet)
1	17	35	2120	1000
2	120	44	420	1000
3	157	27	420	1000
4	165	46	480	1000
5	334	38	480	2000
6	004	30	420	1000
7	342	28	420	1000
8	270	69	420	10,000

(5) Comments. The speed in routes 4 and 5 is increased from 420 to 480 knots because the aircraft formation is in its attack approach at this time. The altitude in route 5 is increased from 1000 ft to 2000 ft because the aircraft formation needs to be formed again after the airport attack. In route 8 alititude is increased because the aircraft formation need to save fuel in order to return to its base.

b. Aircraft Formation 2 (Target 2)

(1) Type. The aircraft formation 2 is a friendly formation and it consists of four interceptor airplanes.

(2) Purpose. The mission of this formation is to intercept enemy aircraft and return to its base (X = 163 NM, Y = 2 NM) for refueling. It penetrates both "HAWK" and "NIKE" radar sites and is included here to demostrate the accidental attrition of friendly aircraft due to human errors (fractricide).

(3) Initial Point and Start Time. Target 2 enters the area at X = 0 NM, Y = 81 NM point 6 minutes after time zero.

(4) Flight Data. The flight routes of Formation 2 consist of three straight lines and the flight data of each flight route are listed below:

Route	Course (degrees)	Length (NM)	Speed (knots)	Altitude (feet)
1	109	37	420	20.000
2	118	44	420	20.000
3	131	64	420	10.000

(5) Comments. The altitude in route 3 changes from 20,000 ft to 10,000 ft because the aircraft formation descends for landing.

c. Aircraft Formation 3 (target 3)

(1) Type. The Aircraft Formation 3 is an enemy formation and it consists of 11 bomber airplanes.

(2) Purpose. The mission of the formation is to to attack the airport whose coordinates are X = 130 NM, Y = 32 NM inside enemy territory. This target's flight plan takes it through two overlapping HAWK radar sites. This will allow an investigation of the command and control model.

(3) Initial Point and Start Time. The aircraft formation enters the enemy area at the point whose coordinates are X = 0 NM, Y = 31 NM and at 5 minutes after time 0.

(4) Flight Data. The flight routes of aircraft Formation 3 consist of seven straight lines and the flight data of each route are listed below:

Route	Course (degrees)	Length (NM)	Speed (knots)	Altitude (feet)
1	Ø88	4Ø	42Ø	1ØØØ
2	Ø5Ø	35	42Ø	1ØØØ
3	111	31	42Ø	1ØØØ
4	Ø82	28	48Ø	1ØØØ
5	249	4Ø	48Ø	2ØØØ
6	299	45	42Ø	1ØØØ
7	28Ø	49	42Ø	1ØØØ

(5) Comments. The speed in route 4 and 5 changes from 42Ø to 48Ø knots because the formation is in its attack phase. The altitude in route 3 increases from 1ØØØ ft to 2ØØØ ft because the formation needs to regroup after attacking the target.

3. Radar Sites

In this particular scenario, there are three HAWK radar sites and one NIKE site. The NIKE site covers almost all the country; the first two HAWK sites are overlaping and cover the entrance to the defended area. The third HAWK site protects a very important industrial town inside the country.

The parameters of four radar sites are shown on Table.

Radar Site	Position (X,Y)	Alt. (feet)	Maximum Detection Range (NM)	Maximum Range of Used Missile (NM)	Radar Missile Capacity	Number of Engaged Targets
HAWK1	(25,26)	1250	25	20	5	1
HAWK2	(37,58)	725	40	30	8	2
HAWK3	(132,62)	1550	40	30	8	2
NIKE	(85,87)	2587	25	87	10	1

C. SUMMARY STEPS OF CALCULATING THE ATTRITION RATE OF ATTACKING AIRCRAFT

In this particular part of chapter IX, a summary of the steps which are required in order to calculate the attrition rate of the attacking aircraft formations are described. The entire process is divided into two parts: preprocessing and dynamic simulation.

1. Preprocessing Phase

Step 1: Initialize the scenario. The user must specify a scenario similar to the scenario described above.

Step 2: Calculate the average terrain altitudes by using the instructions of Chapter II and the computer program "TERRAIN" given in Appendix A. An output of the Average Terrain Model, using the data of the scenario described above, is shown in Appendix G.

Step 3: Calculate the minimum detection altitudes for each radar site by using the instructions of Chapter III

and the computer program "MINALT" given in Appendix B. An output of the Minimum Altitudes Model, using the data of the scenario described above, is shown in Appendix G.

Step 4: Calculate the flight data of each aircraft formation by using the directions of Chapter V and the computer program "CPM" given in Appendix D. An output of the Flight Data Model, using the data of the scenario described above, is shown in Appendix G.

Step 5: Calculate the interception data by using the instructions of Chapter VI and the computer program "INTER" given in Appendix E. An output of the Interception Data Model, using the data of the scenario described above, is shown in Appendix G.

Step 6: Calculate the priority matrix by using the instructions of Chapter VI and the computer program "PRIORITY" given in Appendix E. An output of the Priority Matrix Model, using the data of the scenario described above, is shown in Appendix G.

2. Dynamic Phase

Step 7: Run the "AIRMODEL" program, using the instructions of chapter VIII and the computer program "AIRMODEL" given in Appendix F. An output of the "AIRMODEL" program, using the data of the scenario described above, is shown in Appendix G.

D. EXECUTING THE AIRMODEL

1. Database

This portion of Chapter IX describes and analyzes a complete simulation process following steps one through seven. The scenario which has been used to generate this output is described in the beginning of this chapter. The constant inputs of the computer program "MAIN", in the "AIRMODEL" computer workspace, are as follows:

a. seed = various seeds have been used

b. times = 50 times

c. NSITES= 4

d. DS2 = listed in Appendix G

e. IS2 = listed in Appendix G

f. TGT = 9 4 11

g. MKAP2 = 1 2 2 1

h. MCAP2 = 5 8 8 10

i. PKM = $\begin{vmatrix} 5 & 20 & 25 & 0.5 \\ 5 & 25 & 30 & 0.55 \\ 5 & 25 & 30 & 0.55 \\ 10 & 70 & 85 & 0.4 \end{vmatrix}$

j. IFFFOE= 1

k. ECM = $\begin{vmatrix} 5 & 30 & 80 & 0.7 & 0.85 \\ 5 & 40 & 70 & 0.5 & 0.8 \\ 10 & 50 & 80 & 0.7 & 0.9 \end{vmatrix}$

l. PR = listed in Appendix G.

m. AUTO = 12

n. LBR = 15%

$$p. \quad TSTEP1 = \begin{vmatrix} 1 & 2 & 3 & 2 \\ 2 & 2 & 3 & 2 \\ 1 & 2 & 3 & 2 \\ 2 & 3 & 3 & 3 \end{vmatrix}$$

o. ETSF = 50%

The inputs which will be varied in the airmodel are:

IFF

Probability that IFF works

Probability that IFF is correct given that it works

Command and Control Model

Radar Site Performance Model

Electronic countermeasure means model

2. Result

a. Base Line Situation

The airmodel has been executed with the following various parameters:

IFF = Yes

Probability that IFF works = 0.98

Probability that IFF is correct, given that it works = 0.96

Command and Control Model = Yes

Radar Operation = Normal

ECM = Effective

The setting of these parameters represents a situation which is feasible during conflict operations. The

output of the airmodel is listed in Appendix G. The data analysis is as follows:

(1) Summary Statistics. Some summary AC Attrition statistics are listed below. This data is result of replicting the simulation 50 times.

Statistics	Target 1	Target 2	Target 3
Number of Killed a/c (average)	0.64	0.46	2.2
Sample Variance	0.72	0.25	1.106
Minimum Value	0	0	0
Maximum Value	3	1	5
Range	3	1	5
Median	0	0	2
Low Quantile	0	0	1
Upper Quantile	1	1	3

(2) Distribution Fitting. The most appropriate distribution for the attrition data of the three targets is the binomial with the following parameters:

Parameters	Target 1	Target 2	Target 3
n	9	4	11
p	0.058	0.115	0.24
X square	1.28	3.56	0.87

Since the critical value of X^2 (alpha = 0.05) to reject the null hypothesis (Ho: F(X) = Binomial Distribution) is equal to 7.81 for two degrees of freedom, we accept that the distribution of the attrition rate data is binomial with the parameters shown above.

(3) Confidence Intervals for Probability of Kill. Confidence intervals for the probability of kill are given below for alpha of 0.05.

Target	Probability Function	Confidence Interval	
		Low	Upper
Target 1	P{X=0}=0.56	0.42	0.69
	P{X=1}=0.28	0.15	0.40
	P{X=2}=0.12	0.02	0.21
	P{X=3}=0.04	0.0	0.09
Target 2	P{X=0}=0.54	0.4	0.67
	P{X=1}=0.46	0.32	0.59
Target 3	P{X=0}=0.04	0.0	0.09
	P{X=1}=0.24	0.12	0.35
	P{X=2}=0.34	0.208	0.47
	P{X=3}=0.26	0.13	0.38
	P{X=4}=0.1	0.01	0.18
	P{X=5}=0.02	0.0	0.05

b. Other Ouputs

In this section, some other outputs of "AIRMODEL" are given. These outputs are a result of changing:

1. Probability that IFF works and probability that IFF is correct, given that it works.

2. Command and Control model.

3. Radar site operation model.

4. Electronic countermeasure means model.

(1) Changing the IFF probabilities. In this case, the "AIRMODEL" computer program uses the following input variables.

IFF = Yes

Probability that IFF works = Ø.9Ø

Probability that IFF is correct given that it works = Ø.9Ø

Command and Control Model = Yes

Radar Operation = Good

Electronic countermeasure means model = Yes

These inputs are the same as in the Base Line Situation, above, except the probabilities of IFF.

The means of the output of the target attrition rate data are:

# of A/C	Target 1	Target 2	Target 3	Probabilities
Mean of Attrition Rate	Ø.44	1.42	2.Ø6	IFFWORK = Ø.9Ø IFFWORK = Ø.9Ø
	Ø.64	Ø.46	2.2	IFFWORK = Ø.98 IFFWORK = Ø.96

This table shows that the number of attrited aircraft is less in both targets one and three because more enemy aircrafts pass without interception (recall that the IFF model assumes that if IFF does not work, the detected target is considered to be friend). On the other hand, the the number of destroyed aircraft of target two is greater decause the IFF has a lower degree of reliability. Consequently, there are more fractricides. (Recall that target two is a friendly aircraft formation which is returning for a landing).

(2) Changing Command and Control Input. In this case, there is no command and control model applied. That means that the radar sites operate autonomously. The input variables of "AIRMODEL" are:

IFF = Yes

IFFWORK = Ø.98

IFFCOR = Ø.96

Command and Control Model = No

Radar Operation = Good

Electronic countermeasure means = Yes

These inputs are the same as in the Base Line Situation, except that the command and control model is not applied.

The table, below, shows that the number of destroyed aircraft is greater when command and control is not applied. This result is a suprise because the opposite was expected.

The means of the output of target attrition are given below:

# of A/F	Target 1	Target 2	Target 3	Command and Control model
Attrition Rate	1.08	1.1	2.36	not applied
	0.64	0.46	2.2	applied

However, the result came about because the scenario has only three targets and four radar sites. When one target formation was engaged by radar site one, radar site two was not allowed to engage this target time (IDLE). Therefore, the formation was intercepted only by radar site one and it suffered less attrition. On the other hand, when command and control is not applied, the same target formation is intercepted by more than one radar site and it suffers more attrition (both radar sites are active). This phenomenon would not happen if the scenario had more targets.

(3) Changing the radar site operation model. In this case, the operation of all the radar sites is degraded. The variable inputs of "AIRMODEL" are:

IFF = Yes

IFFWORK = Ø.98

IFFCOR = Ø.96

Command and Control model = Yes

Radar Operation = degraded

Electronic countermeasure means = Yes

These inputs are the same as in the Base Line Situation, above, except that all radar operations are degraded.

The means of the output of target attrition rate data are shown below:

# of A/C	Target 1	Target 2	Target 3	Radar Operation
Attrition Rate	Ø.6Ø	Ø.41	1.42	Degraded
	Ø.64	Ø.46	2.2	Good

The table shows that the number of destroyed aircraft for all three targets is less, as it is expected, when the radar sites work in a degraded mode. This attrition rate has been reduced almost 4Ø%. in the case of Table 3.

(4) Changing the electronic countermeasure means model. In this case, the electronic countermeasure means model (ECM) is not applied. That means that no target formation uses ECM.

The variable inputs of "AIRMODEL" are:

IFF = Yes

IFFWORK = Ø.98

IFFCOR = Ø.96

Command and Control Model = Yes

Radar Operation = Good

Electronic countermeasure means model = No

These inputs are the same as the Base Line Situation, above, except that the electronic countermeasure means model is not applied.

The means of the output of target attrition rate data is shown below:

# of A/C	Target 1	Target 2	Target 3	ECM Model
Attrition Rate	Ø.76	Ø.93	4.Ø6	not applied
	Ø.64	Ø.46	2.2	applied

The table shows that the number of destroyed aircraft is greater when the targets do not use electronic countermeasure means to protect themselves. The increase of number of the destroyed aircraft when ECM is not applied, is approximately 1ØØ%.

3. Sensitivity Analysis

By using the scenario described above, sensitivity analysis can be performed by changing some of the aircraft movement data. For example, by changing the routes that the aircraft formation use, one can see how the attrition rate will be changed. Other parameters that can be changed for sensitivity analysis are the flight altitude and the speed of the aircraft formation.

In this section, sensititvity analysis is performed by changing the flight altitude of the aircraft formations. A change in the flight altitude was performed to study the effects of terrain masking on aircraft attrition rate.

To perform this sensitivity analysis, five different aircraft flight levels were used (500, 1000, 2000, 5000 and 10000 feet). The outputs of the "AIRMODEL", using these five different flight level data, are listed in Appendix G.

The number of destroyed aircraft for each different flight level are given below:

Flight Level	Target 1	Target 2	Target 3	Total
500	0.83	0.13	0.77	1.73
1000	0.64	0.46	2.20	3.30
2000	0.82	0.62	2.25	3.69
5000	0.94	0.65	2.16	3.75
10000	0.96	0.66	2.20	3.82

The table shows the increase in the number of destroyed aircraft as the flight level increases.

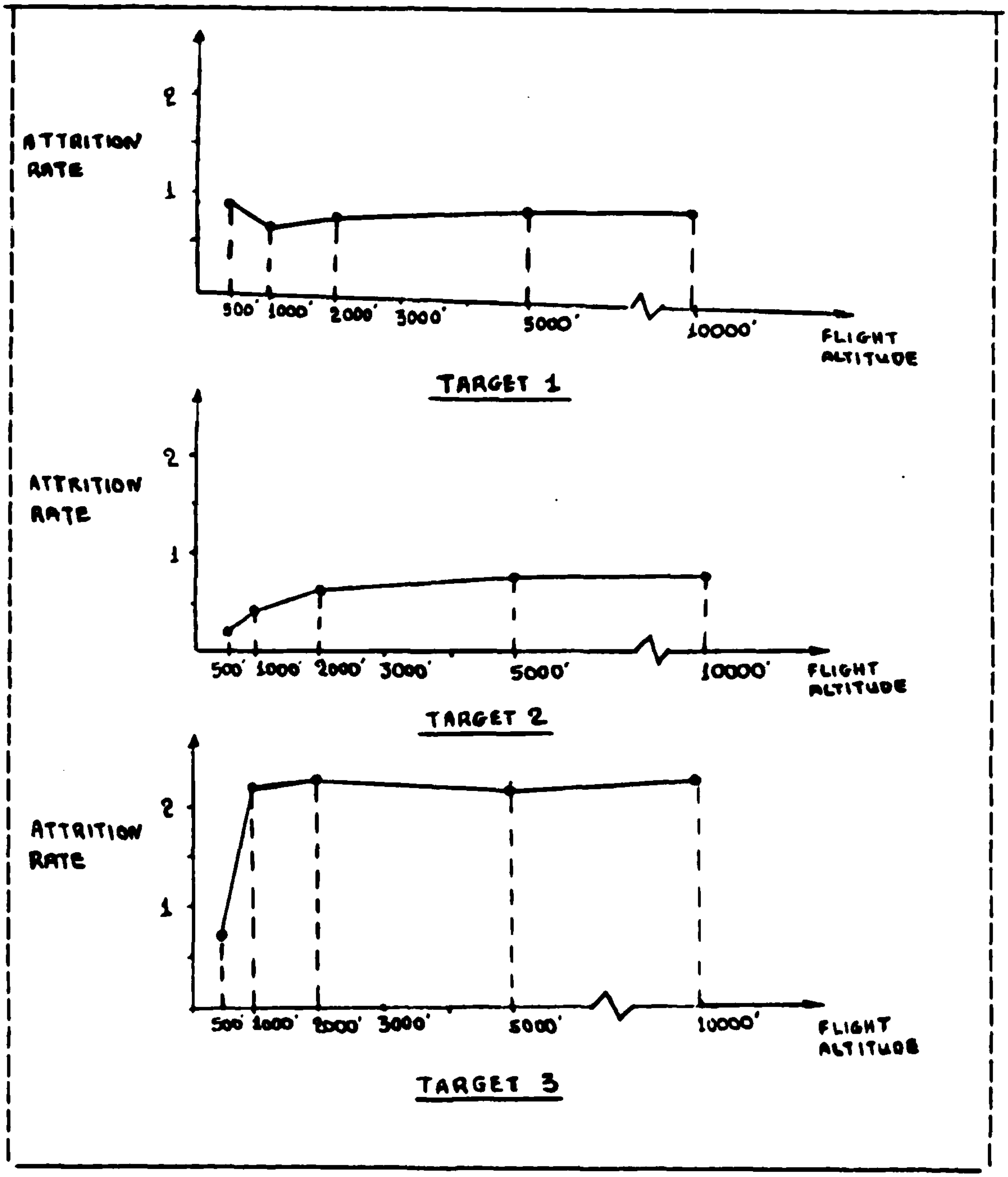

Figure 9.2 Attrtition Rate of Each Target

Figure 9.2 above, shows the change in attrition rate of aircraft as a function of the flight level for each target.

Figure 9.3 below, shows the change in the total attrition rate of the three formations as a function of the flight level.

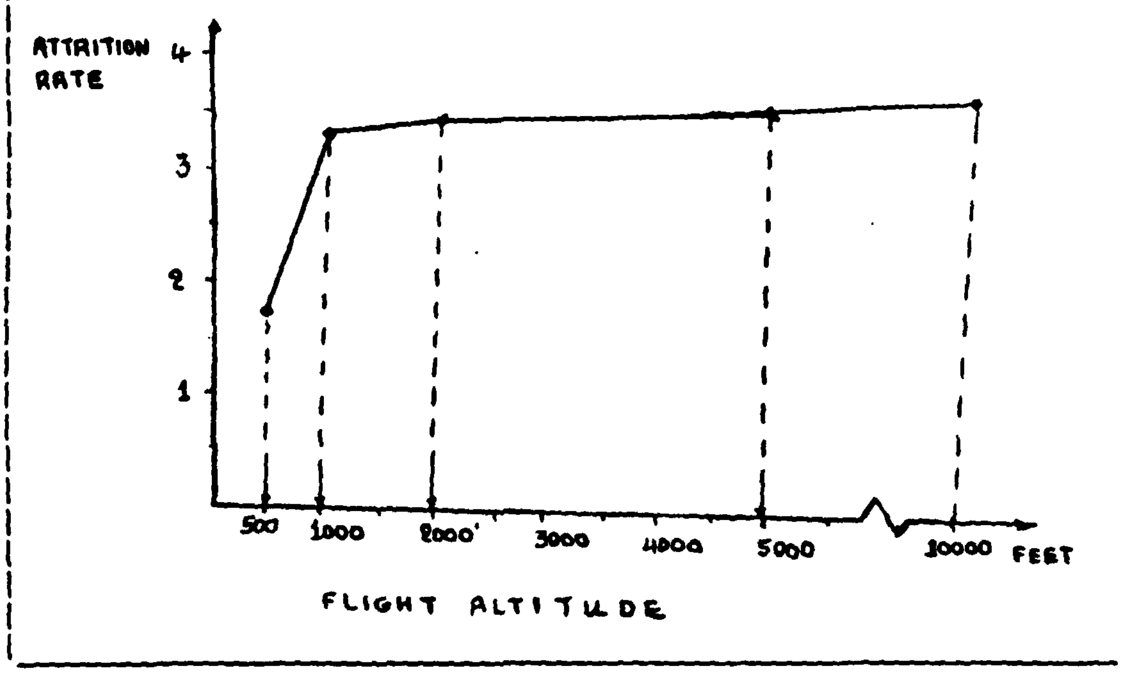

Figure 9.3 Total Attrition Rate

It is worth while considering that the increase in attrition rate, especially for target three, is very large when the formation changes altitude from 500 feet to 1000 feet. However, the attrition rate is essentially constant for altitudes above 2000 feet.

X. SUMMARY AND CONCLUSION

A. SUMMARY

This thesis has presented a high resolution model to analyze the air attack/defense combat situation.

The simulation has made efficient use of off-line, pre-processing submodels and programs in order to compute the deterministic phase of the engagement. By pre-flying the aircraft through the entire scenario, most of the detailed calculations involving the geometry of the air engagement were performed. These calculations were used to determine if detection, tracking, firing, and interception are feasible during all segments of the flight. The information was summarized and stored in the form of matrices whose only elements are zero and one. As a result, the deterministic elements of the air battle were transformed into look-up table for each time step of the simulation.

The pre-processing phase included:

1. Generating the terrain models (Chapters II and III)

2. Modeling the flight paths of all aircraft contained in the simulation(Chapter V)

3. Completing detection, tracking, firing and interception calculations (Chapters IV through VI).

4. Modeling for the effects of IFF, degraded equipment, ECM, target selection priorities, and command and control (Chapter VII).

The results of the pre-processing calculations were input into the dynamic simulation phase of the model. The stochastic portions of the air attack/defense encounter were replicated and summary statistics were gathered and analyzed. A sensitivity analysis was performed to demonstrate the relationship between aircraft altitude and attrition rate. (Chapter VIII and IX)

B. CONCLUSION

The technique of separating the deterministic and stochastic elements of the air battle proved to be very efficient. Using an IBM PC, it required approximately 25 minutes to pre-fly the aircraft and summarize the geometry of the air battle in matrix format. The stochastic portion of the air battle required approximately 8 minutes of executing time. Although these run times are scenario dependent, the three-to-one ratio is a reasonable approximation to the apportionment of time required for both phases of the simulation. Replicating the entire simulation 50 times, without a pre-processing oriented model, would require 1650 minutes of IBM PC time. Using the pre-processing approach, the time required for the same 50 replications is 425 minutes. This represents a savings of approximately 75%.

The submodels developed in this thesis can be used in several ways.

1. The attacker can use the pre-processing models to design flight paths which minimize detection and take more advantage of terrain masking.

2. The attacker can perform trade-off analyses between different approach altitudes. For a given flight path, the attacker can determine the highest altitude which will offer deception and cover and allow for efficient fuel consumption.

3. The attacker can better determine the missile sites which offer the greatest threat of attrition. Air assets can then be allocated to attack these sites and degrade their capability.

4. The defender can use the pre-processing models to improve the positioning of air defense sites, given the likely axis of advance by attacking aircraft.

AIRMODEL allows the analyst to investigate a wide range of aircraft attack/defense problems. The simulation can be efficiently replicated without re-calculating the deterministic phases of the engagement. Consequently, a more realistic and accurate perspective of the encounter can be achieved.

Further research and analyses can be directed towards developing the stochasting sub-models necessary to simulate the engagment sequence. This author has developed a general approach which is efficient and realistic.

Acquisition, tracking, and firing time delays require more study and model design. The user is invited to employ this modeling architecture as a specific framework for model building. The entire simulation model is modular. Therefore, the user can modify the sub models to suit specific design requirement and level of fidelity.

APPENDIX A

A. PURPOSE

This program is used to calculate:

1. The average altitudes for each grid square.

2. To construct a matrix named ATERRAIN whose entries are the average altitudes for grid squares.

B. DESCRIPTION OF THE TERRAIN SIMULATION PROGRAM

The header of the terrain program is "TERRAIN".

1. Input

The "TERRAIN" program prompts one input:

A matrix A whose entries are the altitudes of each grid square. How these numbers are extracted is described in section one. Matrix A does not need to be square. The number of rows is the result of the division of the length of X range by the length of the side of the square grid. For example if the length of the terrain is 60 NM and the length of the side of the grid square is 6 NM, the number of rows of the matrix will be equal to 10. The number of columns is calculated in the same way.

2. Output

The "TERRAIN" program calculates a matrix whose entries are the average heights of grid squares such as shown previously in Table 2.

```
    ∇ TERRAIN;B;C;I;A
 ⍝
 ⍝ THIS FUNCTION CALCULATE THE AVERAGE OF THE HIGHTS OF THE GIVEN TERAIN
 ⍝-------------- INPUT DESCRIPTION-------------------------------------------+
 ⍝ THE  REQUARED INPUT IS A MATRIX WHOSE ENTRIES ARE THE ALTITUDE
 ⍝ OF THE FOUR CORNERS OF EACH SQUARE GRID
 ⍝
 ⍝---------------OUTPUT DESCRIPTION------------------------------------------+
 ⍝ THE OUTPUT IS A MATRIX WHOSE ENTRIES ARE THE AVERAGE ALTITUDE
 ⍝ OF THE SQUARE GRID
 ⍝--------------------------------------------------------------------------+
 ⍝---------------MAIN PROGRAM-----------------------------------------------+
  I←0
 P5:'ENTER THE MATRIX OF THE SQUARE GRIND ALTITUDE'
  A←⎕ ⋄ →((+/(⍴A))<2)/P3 ⋄ →P4
 P3:'THE INPUT IS NOT A MATRIX)' ⋄ →P5
 ⍝-------CREATE THE MATRICES------------------------------------------------+
 P4:B←(((⍴A[;1])-1),(⍴A[1;]))⍴0 ⋄ C←(((⍴A[;1])-1),((⍴A[1;])-1))⍴0
 L1:I←I+1 ⋄ →(I≥(⍴(A[;1])))/L2
  B[I;]←A[I;]+A[(I+1);]
  →L1
 L2:I←0
 L3:I←I+1 ⋄ →(I≥(⍴(B[1;])))/L5
  C[;I]←(B[;I]+B[;I+1])÷4
  →L3
 L5:AHEIGHTS←C
  '                THE MATRIX  ''AHEIGHTS '''
  '                ----------------------'
  AHEIGHTS

    ∇
```

APPENDIX B

This appendix describes the workspace called "MINALT" (MINimum ALTitudes). This workspace contains two functions called "MALTI" and "GRID".

A. FUNCTION "MALTI"

HEADER : The header of the function "MALTI" is MALTI.

PURPOSE: This function calculates the minimum altitude where a given radar site can "see" a target due to terrain masking and to limitation of the maximum range.

INPUT: The function "MALTI" prompts four inputs:

1. A three element vector which contains the position and the altitude of the radar site.

   (a) X,Y cordinates in square grid position. For example, if the radar site is located in square grid (7,3) then first two elements are 7 3.

   (b) Radar site altitude (in feet). Thus the completed input is 7 3 1000

2. The maximum range of the radar site in NM

3. A (N,M) matrix containings the average altitudes of the grid squares calculated by the program "TERRAIN" described in Appendix A of Chapter 2.

4. A scale factor, describing the size of the

grid squares desired. Its measurement is in Nautical Miles (N.M).

OUTPUT: The output is a (N M) matrix whose entries are the minimum altitudes above which a given radar site can detect a target.

B. FUNCTION "GRID"

HEADER : The header of the function "GRID" is SITE GRID CORD.

PURPOSE: This function finds the grid squares which exist between the radar site and the target grid square. For example, if the radar site is located in grid square (2,1) - see Figure 3.1 in Chapter 3 - and the target square is (4,4), then the intermediate grid squares given by the function "GRID" are (2,2), (3,2) and (3,3). This function supports the previous function "MALTI" but it can be run separately, as well.

INPUT: The function "GRID" prompts two inputs:

1. A three element vector which contains the coordinations of the radar site X, Y and its altitude. This vector is the left argument of the function's header (SITE).
2. The coordinations of the target square grid X,Y. this input is the right argument of the function's header (CORD).

OUTPUT: The output of this program is a (2 N) matrix whose columns are the coordinates of the square

grids which lay between the radar site and the target square grid.

```
    ∇ GR←SITE GRID CORD;I;A;XX1;XX2;A1;X1;X2;XX;YY;Y1;Y2;F;VEC;X;Y;R
  ⍝
  ⍝====================== PURPOSE ===================================+
  ⍝ THIS FUNCTION IS USED TO FIND THE SQUARE GRIDS WHICH ARE
  ⍝ BETWEEN THE RADAR SITE AND THE SQUARE TARGET GRID.
  ⍝
  ⍝====================== INPUT =====================================+
  ⍝ 1. THE CORDINATIONS OF THE RADAR SITE: X,Y AND ALTITUDE (IN FEET)
  ⍝ 2. THE CORDINATIONS OF THE SQUARE TARGET GRID: X,Y .
  ⍝
  ⍝===================== OUTPUT =====================================+
  ⍝ A (2 N) MATRIX WHOSE COLUMNS ARE THE CORDINATES OF THE SQUARE
  ⍝ GRIDS WHICH LAY BETWEEN THE RADAR SITE AND THE SQUARE
  ⍝ TARGET GRID.
  ⍝===================== MAIN PROGRAM ===============================+
   I←1
   X1←SITE[1]-0.5 ⋄ X2←CORD[1]-0.5
   Y1←SITE[2]-0.5 ⋄ Y2←CORD[2]-0.5
  ⍝-------THE DISTANCE ----------------------------------------------+
   R←(((X2-X1)*2)+((Y2-Y1)*2))*0.5
  ⍝-------THE VECTOR ------------------------------------------------+
   VEC←((⍳(⌊R)×5))÷5
   →((X2-X1)≠0)/L13
   X2←X2+0.1
  L13:F←(¯3)○((Y2-Y1)÷(X2-X1))
  ⍝-------- X Y CALCULATION ----------------------------------------+
   X←(2○F)×VEC ⋄ Y←(1○F)×VEC
   →(((X2-X1)≥0),((Y2-Y1)<0))/L3,L3
   XX←X1-X ⋄ YY←Y1-Y ⋄ →L6
  L3:→((Y2-Y1)<0)/L5
   YY←Y1+Y ⋄ XX←X1+X ⋄ →L6
  L5:YY←Y1-Y ⋄ XX←X1-X
   →(((X2-X1)≤0),((Y2-Y1)>0))/L6,L6
   YY←Y1+Y ⋄ XX←X1+X
  L6:A←⌈(2,(ρVEC))ρXX,YY
   →((ρA[1;])≠0)/RR10
   GR← 2 1 ρ⌊(SITE[1],SITE[2]) ⋄ →LLL2
  RR10:A1←A[;1]
  ⍝-- REJECT THE CASE WHEN THE GRID[I] IS = GRID[I+1] --------------+
  L2:→((A[1;I])=(A[1;I+1]))/L1
   →L12
  L1:→((A[2;I])=(A[2;I+1]))/L11
  L12:A1←A1,A[;I+1]
  L11:I←I+1
   →(I<(ρVEC))/L2 ⋄ GR←⍉(((ρA1)÷2),2)ρA1
   XX1←GR[1;]
   XX2←GR[2;]
  ⍝--- REJECT THE CASE WHEN THE GRID IS THE SAME WITH THE SITE -----+
   →((1↑XX1)≠(⌊SITE[1]))/LL5
   →((1↑XX2)≠(⌊SITE[2]))/LL5
   XX1←1↓XX1 ⋄ XX2←1↓XX2 ⋄ GR←(2,(ρXX1))ρXX1,XX2
  ⍝--- REJECT IF THE CORDINATIONS ARE ZERO-------------------------+
  LL5:→((¯1↑XX1)=0)/LLL3
   →((¯1↑XX2)=0)/LLL3
   →LLL2
  LLL3:XX1←¯1↓XX1 ⋄ XX2←¯1↓XX2
   GR←(2,(ρXX1))ρ(XX1,XX2)
  LLL2:GR←GR,CORD
```

```
    ∇ MALTI;COS1;COS2;SIN1;SIN2;L;P;A1;G;GR;D1;D2;GGR;GO;GRM;H;I;J;K;R;SC
ALE;ALT1;ALT2;CORD;D3;NM;TH;TH1;TH2;TH3;TH4;TH5;SSITE
⍝
⍝===================== PURPOSE ===================================+
⍝ THIS FUNCTION CALCULATE THE MINIMUM ALTITUDE THAT A THE GIVEN
⍝ RADAR SITE CAN SEE A TARGET DUE TO MAXIMUM RANGE AND TO TERRAIN
⍝ MASKING
⍝
⍝===================== INPUT =====================================+
⍝  1. A THREE ELEMENT VECTOR FOR THE RADAR SITE POSITION
⍝       (A). X Y CORDINATES IN SQUARE GRID POSITION
⍝       (B). RADAR SITE ALTITUDE (IN FEET)
⍝
⍝  2. THE MAXIMUM RANGE OF THE RADAR SITE IN N.M
⍝
⍝  3. A (N M) MATRIX WITH THE AVERAGE ALTITUDES (GIVEN BY THE TERRAIN
⍝     SIMULATION)
⍝
⍝  3. THE SCALE FACTOR (THE LENGTH OF THE SQUARE GRIDS) IN N.M
⍝
⍝=================== OUTPUT =====================================+
⍝ THE OUTPUT IS A (N M) MATRIX WITH THE MINIMUM ALTITUDES
⍝ ABOVE OF WHICH A GIVEN RADAR SITE CAN SEE A TARGET
⍝
⍝=================== MAIN PROGRAM ==============================+
⍝
T2:'ENTER THE SITE DATA (X,Y,ALTITUDE)'
 SITE←⎕ ⋄ SSITE←(⌈((2↑SITE)÷6)),¯1↑SITE ⋄ SITE ⋄ SSITE
 →((⍴SSITE)=3)/T1
 'THE VECTOR IS NOT CORRECT !!! TRY AGAIN' ⋄ →T2 ⋄ ' '
 ''
T1:'ENTER THE MAXIMUM RANGE OF THE RADAR SITE (IN N.M)'
 RANGE←⎕
 ' '
T4:'ENTER THE AHEIGHTS MATRIX'
 H←⎕
 →((⍴H)≥1)/T3
 'THE MATRIX DOES NOT HAVE CORRECT DIMENTIONS TRY AGAIN' ⋄ →T4
 ' '
T3:'ENTER THE SCALE FACTOR'
 SCALE←⎕
 J←1 ⋄ H1←(⍴H)⍴0
PP4:I←1
PP3:CORD←(I),(J) ⋄ K←1 ⍝⋄ 'I,J = ',⍕I,J
 GO←(((I×SCALE)-(SCALE÷2)),((J×SCALE)-(SCALE÷2))) ⍝⋄ 'GO=',⍕GO
 R←3455 ⋄ NM←6067 ⋄ ⍝SITE←(((⌊SSITE[1,2]×SCALE))-(SCALE÷2)),SSITE[3]
 L←(((GO[1]-SITE[1])*2)+((GO[2]-SITE[2])*2))*0.5
 →(L≤RANGE)/T4
 H1[I;J]←¯1 ⋄ →END
⍝-----------------------------------------------------------------+
⍝ FIND THE GRID BETWEEN THE RADAR SITE AND THE TARGET GRID
T4:GR←SSITE GRID CORD
⍝-----------------------------------------------------------------+
 GR←⍉GR ⋄ GRM←(⍴(GR[1;]))⍴0 ⍝⋄ GR
PP1:GGR←GR[;K]
 G←(((⍉GR[;K])×(SCALE))-(SCALE÷2)),H[(GGR[1]);(GGR[2])] ⍝⋄ 'G=',⍕G
⍝-----------------------------------------------------------------+
⍝CALCULATION OF THE DISTANCE(CURVE)
 D1←(((G[1]-SITE[1])*2)+(((G[2])-SITE[2])*2))*0.5 ⍝⋄ ' D1= ',⍕D1
 D2←(((GO[1]-SITE[1])*2)+((GO[2]-SITE[2])*2))*0.5 ⍝⋄ ' D2= ',⍕D2
⍝-----------------------------------------------------------------+
⍝ CALCULATE THE ANGLES
 TH1←D1÷R ⋄ TH2←D2÷R ⋄ TH←TH1+TH2 ⍝⋄ TH1,TH2,TH
 ALT1←R+(SITE[3]÷NM) ⋄ ALT2←R+(G[3]÷NM) ⍝⋄ ALT1,ALT2
 COS1←2○TH1 ⋄ COS2←2○TH2 ⍝⋄ COS1,COS2
⍝-----------------------------------------------------------------+
⍝ CALCULATION OF THE ACTUAL DISTANCE
 D1←3455×((2×(1-COS1))*0.5) ⍝⋄ 'DD1=',⍕D1
 D2←3455×((2×(1-COS2))*0.5) ⍝⋄ 'DD2=',⍕D2
```

```
 →(D2≠0)/TT2
 A1←¯10 ⋄ →TT1
TT2:D3←(((ALT1*2)+(ALT2*2))-(2×ALT1×ALT2×COS1))*0.5 ⍝⋄ 'D3= ',⍕D3
 TH3←(((D3*2)+(ALT1*2))-(ALT2*2))÷(2×D3×ALT1) ⍝⋄ 'TH3=',⍕TH3
 TH4←¯2○TH3 ⍝⋄ 'TH4=',⍕TH4
 TH5←(○1)-(TH4+TH2) ⍝⋄ 'TH5=',⍕TH5
 SIN1←1○TH5 ⋄ SIN2←1○TH4 ⍝⋄ SIN1,SIN2
 A1←(((SIN2×ALT1)÷SIN1)-R)×(NM) ⍝⋄ 'AA1=',⍕A1
⍝-----------------------------------------------------------+
TT1:GRM[K]←A1 ⍝⋄ A1
 K←K+1 ⋄ →(K>(⍴GR[1;]))/PP2
 →PP1
⍝-----------------------------------------------------------+
⍝ TAKE THE LARGEST ALTITUDE
PP2:H1[I;J]←1↑(GRM[⍒GRM]) ⍝⋄ 'FIN ALT= ',⍕H1[I;J]
⍝'------------------------------------------'
END:I←I+1
 →(I≤(⍴H[;1]))/PP3
 J←J+1
 →(J≤(⍴H[1;]))/PP4 ⋄ H1[(SSITE[1]);(SSITE[2])]←¯10
 '                    THE SMALLEST ALTITUDE ARE'
 '                    -------------------------'
 H1←⌈H1
 ''
 ''
 'NOTE'
 '----'
 ''
 '  +--------------------------------------------------------+'
 '        THE OUTPUT IS STORED UNTER THE VARIABLE H1'
 '  +--------------------------------------------------------+'
∇
```

APPENDIX C

Appendix C describes the computer function named "CONTOUR".

HEADER : The header of the function CONTOUR is "CONTOUR"

PURPOSE: This function calculates if a given radar site can detect a target flying at a given altitude level for all the square grids which are located inside the radar site maximum distance.

INPUT : The computer function "CONTOUR" prompts three inputs:

1. A (N M) matrix given by the terrain simulation functions "TERRAIN" described in Appendix A.
2. The altitude of the target (in feet).
3. A (N M) matrix given by the minimum altitude simulation function "MALTI", described in Appendix B.

OUTPUT : The output is a (N M) matrix the entries of which are -10, -1, 0 and 1. The meaning of these numbers are as follows:

-10 = Position of radar site.

-1 = Radar site can not detect the target because it flies out of the radar maximum range.

0 = Radar site can not detect the target

because there is no line-of-sight, and

1 = Radar site can detect the target.

The output matrix is stored under the variable CON.

```
    ∇ CONTOUR;ALT1;ALT2;ALT3;ALT4;I;J;H
  ⍝
  ⍝==================== PERPOSE ==================================+
  ⍝ THIS FUNCTION CALCULATE A TABLE WHICH ILLUSTRATE IF A
  ⍝ A PARTICULER RADAR SITE CAN SEE THE TARGET OR NOT.
  ⍝
  ⍝=================== INPUT =====================================+
  ⍝ 1. A (N M) MATRIX OF TERRAIN ALTITUDE(FROM TERRAIN SIMULATION)
  ⍝ 2. THE ALTITUDE OF THE TARGET
  ⍝ 3. A (N M) MATRIX OF RADAR SITE MINIMUM ALTITUDE
  ⍝
  ⍝==================== OUTPUT ===================================+
  ⍝ A (N M) MATRIX WITH ELEMENT OF ¯10 ¯1  0 AND 1.
  ⍝
  ⍝ ¯10 = RADAR SITE POSITION
  ⍝  ¯1 = RADAR SITE CAN NOT SEE THE TARGET BECAUSE OF THE MAX. RANGE
  ⍝   0 = RADAR CAN NOT SEE THE TARGET BECAUSE OF LINE-OF-SIGHT
  ⍝   1 = RADAR CAN SEE THE TARGET
  ⍝
  ⍝=================== MAIN PROGRAM ============================+
   'ENTER THE TARGET ALTITUDE (IN FEET)'
   H←⎕ ⋄ H
  ⍝ H←1000
   'ENTER THE MATRIX OF THE AVERAGE TERRAIN ALTITUDES'
   ALT1←⎕ ⍝⋄ ALT1
  ⍝ALT1←MM
   'ENTER THE MATRIX OF THE MINIMUM ALTITUDES OF THE RADAR SITE'
   ALT2←⎕ ⍝⋄ ALT2
  ⍝ ALT2←H2
   I←J←1 ⋄ CON←((ρALT1[;1]),(ρALT1[1;]))ρ0
  L3:I←1
  L2:ALT3←ALT1[I;J]+H ⍝⋄ 'ALT1+H =',⍕ALT3 ⋄ I,J
   ALT4←ALT2[I;J] ⍝⋄ 'ALTSITE=',⍕ALT4
   →((ALT2[I;J])≠¯10)/L7
   CON[I;J]←¯10 ⋄ →L4
  L7:→(ALT4≠¯1)/L1
   CON[I;J]←¯1 ⋄ →L4
  L1:→(ALT4≤ALT3)/L6
   CON[I;J]←0 ⋄ →L4
  L6:CON[I;J]←1
  L4:I←I+1
   →(I≤(ρALT1[;1]))/L2
   J←J+1
   →(J≤(ρALT1[1;]))/L3
   '            THE OUTPUT IS:'
   '            -------------'
   ''
   CON
   'THE OUTPUT IS STORED UNDER THE VARIABLE CON'
    ∇
```

APPENDIX D

Appendix D describes the computer function named "MOVEMENT" and it has two functions: CPM and ERROR.

A. CPM

HEADER : The header of the function CPM is "CPM".

PURPOSE: This function calculates the time steps, the position, the altitude over this position and the direction of all flight legs of all aircraft for each time step.

INPUTS : The computer function "MOVEMENT" prompts the following inputs:

1. Time Step: The time of the time step of model (in seconds) i.e. if the calculation has to be done every 10 seconds, the input for time step must be 10.
2. Scale: The scale used for the terrain simulation, i.e. the length of the side of the terrain square grid.
3. Alt. Data: The average altitudes given by the terrain model (in feet).
4. XØ, YØ, TØ: Cordinates and time for the beginning of the flight path (in NM for cordinates and minutes for time).
5. Dir: The direction of the flight path of the aircraft (in degrees).

6. Length: The length of the flight leg of the aircraft (in NM).

7. Speed: The speed of the aircraft along the flight path (in NM).

8. Alt: The altitude of the aircraft along the flight path (in feet).

OUTPUT : The output is a (5,N) matrix whose elements are as follows:

1. First Row: Time steps of the air combat model.

2. Second and Third Row: The Cartesian coordinates of the position of all aircraft for all time steps.

3. Fourth Row: The altitude

4. Fifth Row: The course of each flight leg.

5. N: The number of the time steps.

The output is stored under the variable A1.

B. ERROR

This function is used in all the models and informs the user about a wrong input.

```
    ∇ CPM;DPTI;TSPGD;ALT;DATA;DIR;DISTANCE;I;Q1;Q2;SCALE;SPEED;TI;X;X1;Y1;X0;XYA
;Y0;Y;T0;T1;V;V1;V2;T1;Z;Z1;VECTOR;XYT;FDATA1
[1]   ⍝
[2]   ⍝------------------------ PURPOSE -------------------------------------+
[3]   ⍝
[4]   ⍝    THE PURPOSE OF THIS PROGRAM IS TO CALCULATE THE TIME STEPS,
[5]   ⍝    POSITION(X,Y), THE ALTITUDE OF THE A/C FOR THE PENETRATION
[6]   ⍝    ROUTE ACROSS THE HOSTILE AREA, THE COURSE AND THE SPEED FOR
[7]   ⍝    EACH FLIGHT LEG FOR ALL THE TIME STEPS.
[8]   ⍝
```

```
⍝------------------------- INPUT ---------------------------------+
⍝
⍝   1. TIME STEP = THE TIME OF THE TIME-STEP MODEL YOU LIKE (IN SECOND)
⍝                  I.E IF YOU LIKE THE CALCULATION TO BE DONE EVERY
⍝                  10 SECOND ENTER FOR TIME STEP: 10
⍝
⍝   2. SCALE     = THE SCALE USED FOR THE TERRAIN SIMULATION. I.E THE
⍝                  LENGTH OF THE SIDE OF THE TERRAIN SQUARE GRID.
⍝                  (IN  N.M)
⍝
⍝   3. ALT.DATA  = THE AVERAGE ALTITUDES GIVEN BY THE TERRAIN
⍝                  MODEL. (IN FEET)
⍝
⍝   4. XO,YO,TO  = CORDINATES AND TIME FOR THE FLIGHT PATH BEGGINING.
⍝                  ( IN N.M FOR CORDINATES AND IN MINUTES FOR TIME)
⍝
⍝   5. DIR       = THE DIRECTION OF THE FLIGHT PATH (IN DEGREE).
⍝
⍝   6. LENGTH    = THE LENGTH OF THE FLIGHT PATH (IN N.N).
⍝
⍝   7. SPEED     = THE SPEED OF THE A/C ACROSS THE FLIGHT PATH (IN N.M)
⍝
⍝   8. ALT.      = THE ALTITUDE OF THE A/C ACROSS THE FLIGHT PATH
⍝                  (IN FEET)
⍝
⍝------------------------ OUTPUT ----------------------------------+
⍝
⍝   THE OUTPUT IS A (4 N) MATRIX WHOSE  ROWS AND N ARE AS FOLLOWS:
⍝
⍝     1. THE FIRST ROW IS THE TIME STEPS
⍝     2. THE SECOND AND THE THIRD ROWS ARE THE A/C POSITION
⍝        IN X,Y CORDINATES,
⍝     3. THE FOURTH ROW IS THE A/C ALTITUDE ACROSS THE FLIGHT PATH
⍝     4. THE FIFTH ROW IS THE HEADING OF THE FLIGHT PATH
⍝     5.THE SIXTH ROW IS THE SPEED OF A/C FOR EACH FLIGHT LEG.
⍝
⍝---------------- OUTPUT FOR CHECK --------------------------------+
⍝    FLIGHT DATA ARE STORED UNDER THE VARIABLE FDATA
⍝    AS FOLLOWS:
⍝      FIRST ROW  = DIRECTION FOR EACH FLIGHT SEGMENT
⍝      SECOND ROW = LENGTH OF EACH FLIGHT SEGMENT
⍝      THIRD ROW  = SPEED OF A/C FOR EACH FLIGHT SEGMENT
⍝      FOURTH ROW = ALTITUDES OF A/C FOR EACH FLIGHT SEGMENT
⍝
⍝---------------------- PROGRAM ----------------------------------+
⍝
 V2←0 ⋄ A1← 6 0 ⍴0 ⋄ FDATA1← 4 1 ⍴0 ⋄ FDATA← 4 0 ⍴0
⍝----------- ENTER DATA ---------------------------------------+
 'ENTER THE TIME STEP (IN SECOND)'
 TI←⎕ ⋄ ''
 'ENTER THE AVERAGE ALTITUDES FROM TERRAIN SIMULATION (TDATA)'
 DATA←⎕ ⋄ ' '
 'ENTER THE SCALE OF THE TERRAIN SIMULATION GRID (IN N.M)'
 SCALE←⎕ ⋄ ' '
L2:'--------- ENTER FLIGHT DATA -----------'
 ''
L7:'IF THE FLIGHT PATH IS A NEW ONE ENTER      0 '
 'IF THE FLIGHT PATH CONTINIUS  ENTER          1 '
 Q1←⎕
 →((Q1=0),(Q1=1),(Q1>1))/L3,L6,L5
L3:'ENTER ( XO,YO,TO ) '
 XYT←⎕
 →((⍴XYT)=3)/L12
 ERROR ⋄ →L3
L12:XO←XYT[1] ⋄ YO←XYT[2] ⋄ TO←XYT[3] ⋄ T1←(TO×60)÷TI
 Z1←(6,(⍴⍳T1))⍴0 ⋄ Z1[1;]←(V2+(⍳T1)) ⋄ V2←T1+V2 ⋄ →L15
 →L6 ⋄ ' '
L5:ERROR ⋄ ' ' ⋄ →L7
L6:' ' ⋄ Z1← 6 0 ⍴0
```

```
[78] L15:'ENTER THE DIRECTION OF THE FLIGHT PATH (IN DEGREE)'
[79]  DIR←⎕ ⋄ ' ' ⋄ FDATA1[1;]←DIR
[80]  →(DIR≤360)/L20
[81]  ERROR ⋄ →L15
[82] L20:'ENTER THE LENGTH OF THE LEG OF THE FLIGHT PATH (IN N.M)'
[83]  DISTANCE←⎕ ⋄ ' ' ⋄ FDATA1[2;]←DISTANCE
[84] L21:'ENTER THE SPEED OF A/C (IN KNOTS)'
[85]  SPEED←⎕ ⋄ ' ' ⋄ FDATA1[3;]←SPEED
[86]  'ENTER THE FLIGHT ALTITUDE OF A/C (IN FEET)'
[87]  ALT←⎕ ⋄ ' ' ⋄ FDATA1[4;]←ALT ⋄ FDATA←FDATA,FDATA1
[88] ⍝-----------------------------------------------------------------+
[89]  DPTI←(SPEED÷3600)×TI ⍝(DISTANCE PER TIME INCREMENT)
[90]  TSPGD←DISTANCE÷DPTI ⍝(TIME STEPS PER GIVEN DISTANCE)
[91]  VECTOR←(⍳(⌊TSPGD))×DPTI ⍝PER TIME INCREMENT)
[92]  V←V2+⍳(⌊(¯1↑VECTOR)) ⋄ V1←V ⋄ V←¯1↑V
[93] ⍝------------------------------------------------------------------+
[94] ⍝FIND X AND Y CORDINATES
[95] ⍝------------------------------------------------------------------+
[96]  X←X0+VECTOR×(1○(((○1)÷180)×DIR)) ⍝⋄ ⌈X
[97]  Y←Y0+VECTOR×(2○(((○1)÷180)×DIR)) ⍝⋄ ⌈Y
[98]  X1←⌈(X÷SCALE) ⍝⋄ X1=CORD.IN GRID
[99]  Y1←⌈(Y÷SCALE) ⍝⋄ Y1=CORD.IN GRID
[100] ⍝-----------------------------------------------------------------+
[101] ⍝ CREATE THE TIME-POSITION-ALTITUDE-DIRECTION-SPEED MATRIX
[102] ⍝-----------------------------------------------------------------+
[103] ⍝A1←(6,(T1))⍴0 ⋄ A1[1;]←⍳T1
[104]  I←1 ⋄ XYA←(6,(⍴X1))⍴0
[105] L1:XYA[;I]←(⌊V1[I]),(⌈X[I]),(⌈Y[I]),(DATA[X1[I];Y1[I]]+ALT),DIR,SPEED
[106]  I←I+1
[107]  →(I≤(⍴X1))/L1
[108]  A1←A1,Z1,XYA ⋄ X0←¯1↑X ⋄ Y0←¯1↑Y ⋄ V2←¯1↑(A1[1;])
[109] L10:'IF YOU LIKE TO CONTINUE ENTER      0 '
[110]  '    OTHERWISE ENTER                   1 '
[111]  Q2←⎕
[112]  →((Q2=0),(Q2=1),(Q2>1))/L2,L8,L9
[113] L9:'WRONG ENTRY... TRY AGAIN' ⋄ →L10
[114] L8:
[115] ⍝ →(T0≠0)/L11
[116] ⍝ A1← 0 1 ↓A1
[117]  ' ' ⋄ A1 ⋄ ' ' ⋄ ' '
[118]  '             ----------------------------------------------- '
[119]  '                 THE OUTPUT IS STORED UNDER THE VARIABLE A1'
[120]  '             ----------------------------------------------- '
     ∇
```

APPENDIX E

The purpose of this Appendix is to describe the work spaces of the "TARGET DETECTION", "TARGET INTERCEPTION", and "PRIORITY" models.

A. TARGET DETECTION MODEL

The TARGET DETECTION work space is called "FDETECT" and it consists of two functions: DETECT and ERROR.

1. Detect

PURPOSE: The purpose of the function "DETECT" is to find out if a particular site can detect targets which are flying over the hostile terrain in specified altitudes and routes.

INPUT: This function prompts two inputs:

1. The minimum altitudes of the radar site given by the "MINALT" computer work space.
2. The flight data of the targets given by the "MOVEMENT" computer work space.

OUTPUT: The output of this function is a (M,N+1) matrix where:

K = The number of time steps

The first column is the time step

N = The number of target.

2. Error

See Appendix D

B. "TARGET INTERCEPTION" MODEL

The "TARGET INTERCEPTION" work space is called "INTERCPT" and it consists of two functions: INTER and ERROR.

1. Inter

PURPOSE: The purpose of the function "INTER" is to calculate Interception Data (INTERCEPTION STATE MATRIX).

INPUT: The function INTER prompts the following inputs:

1. The time of the time step of the simulation (in sec).
2. The location (X,Y) of the missile radar site (in N.M.).
3. The detection file (detects 1 or 2 etc), given by the "FDETECT" workspace, of the radar site which supports the interceptor missile.
4. The maximum range of the interceptor missile (in N.M.).
5. The speed of the interceptor missile (in knots).
6. The flight target data (target 1 or 2 etc), given by the "MOVEMENT" workspace for each target.

   Note: The order of entering the flight data of the targets must be in ascent order i.e. the target 1 must be entered

first, the target 2 second and so on until all targets are entered in the program.

OUTPUT: The output of this program is a (N, 1+(M*3)) matrix, where:

K = The number of time steps

The first column is the time steps from 1 to K

N = The number of targets

Each target has two columns:

First column = 1, if the interception is possible.

Ø, if the interception is not possible.

Second column = The number of time steps that a possible interception takes, otherwise zero.

Third column = The distance between radar site and target.

C. "TARGET PRIORITY" MODEL

The TARGET PRIORITY model computer workspace is called "PRIORITY" and it consists of one function: PRIORITY.

1. Priority

PURPOSE: The purpose of the function "PRIORITY" is to calculate the priority of each target when a radar site detects more than one target simultaneously.

INPUT: This function prompts two inputs:

1. The critical course to which the target flight courses will be compared.
2. The target flight data given by the "MOVEMENT" computer program.

OUTPUT: The output of this function is a (m, 1+N) matrix, where:

K = The number of time steps from Ø to M

The first column is the time steps

N = The number of targets.

The values in the matrix represent priority number.

```
 ∇ DETECT;A;A2;X;SX;Y;SY;TGT;ZERO;M;D;K;R;I;A1;ALT;KK;MALT;MALTI;P
 ⍝
 ⍝----------------------- PURPOSE ------------------------------+
 ⍝
 ⍝ THIS PROGRAM IS USED TO FIND OUT IF A PARTICULAR RADAR SITE
 ⍝ CAN 'SEE' TARGETS WHICH ARE FLYING OVER THE HOSTILE TERRAIN
 ⍝ IN SPECIFIED ALTITUDES AND ROUTES.
 ⍝
 ⍝----------------------- INPUTS -------------------------------+
 ⍝
 ⍝ THIS PROGRAM PROMPTS TWO INPUTS:
 ⍝
 ⍝ 1. THE MINIMUM ALTITUDES OF THE RADAR SITE GIVEN BY THE 'MINALT'
 ⍝    PROGRAM.
 ⍝ 2. THE FLIGHT DATA OF THE A/C (TARGET1 OR 2 ETC) GIVEN BY THE
 ⍝    PROGRAM 'MOVEMENT'.
 ⍝
 ⍝----------------------- OUTPUTS ------------------------------+
 ⍝  THE OUTPUT OF THIS PROGRAM IS A (M N) MATRIX WHERE:
 ⍝
 ⍝  M = THE NUMBER OF TIME STEPS
 ⍝  N = THE NUMBER OF TARGETS
 ⍝
 ⍝---------------------- MAIN PROGRAM --------------------------+
 ⍝
  D←A1←⍳0
  'ENTER THE MINIMUM ALTITUDES OF THE RADAR SITE ( MALTIS1,2, ETC )'
  MALTI←⎕
 L4:'ENTER THE TARGET FLIGHT DATA ( TARGET1,2,ETC )'
  TGT←⎕
  →((ρTGT[;1])=6)/L3
  ERROR ⋄ →L4
 L3:K←0 ⋄ D←D,(ρTGT[2;]) ⋄ SX←⌈(TGT[2;]÷6) ⋄ SY←⌈(TGT[3;]÷6) ⋄ P←ρSX
 L10:K←K+1
  ALT←TGT[4;][K] ⋄ X←SX[K]
  →(X≠0)/L12 ⍝ CHECK IF THE TARGET HAS ENTERED INTO THE HOSTILE AREA
```

```
  A1←A1,0 ⋄ →L13
L12:MALT←MALTI[X←SX[K];Y←SY[K]] ⍝⋄ X ⋄ Y ⋄ MALT ⋄ ALT
  →(MALT≠¯1)/L9 ⍝ CHECK IF THE TGT IS INSIDE THE MAX RANGE OF SITE.
  A1←A1,0 ⋄ →L13
L9:→(ALT>MALT)/L11 ⍝- CHECK IF THE ALT OF THE TGT IS HIGHER THAN
⍝-------------------- THE RADAR SITE ALTITUDE.
  A1←A1,0 ⋄ →L13
L11:A1←A1,1
L13:→(K<P)/L10
  ''
  'IF YOU HAVE AN ANOTHER TARGET ENTER  0'
  'IF YOU LIKE TO EXIT            ENTER  1'
  KK←⎕
  →(KK=0,KK=1,KK≥2)/L4,L7,L6
L6:ERROR ⋄ →L7
L7:A2←((ρD),(M←1↑(D[⍒D])))ρ0
  I←1
L8:A2[I;]←((D[I]↑A1),(M-D[I])ρ0) ⋄ A1←D[I]↓A1 ⋄ I←I+1
  →(I≤(ρD))/L8
  A3←(((M,1)ριM),⍉A2)
  A3
  '' ⋄ ''
  '---------------------------------------------------'
  '      THE OUTPUT IS STORED UNDER THE VARIABLE A3'
  '---------------------------------------------------'
```

```
    ∇ INTER;A;ANS;D;DF;DF1;DIR;I;K;L;M;MM;Q;RMAX;RO;RO1;SPEED;T;TGT;TI;V1;V2;VR;
W;W2;X0;X1;XR;XS;XT;AC;TEST;AA;DIST
  ⍝ ⍝--------------------- PURPOSE ----------------------------------+
  ⍝
  ⍝  THIS PROGRAM IS USED TO CALCULATE THE INTERCEPTION STATE MATRIX
  ⍝  FOR EACH RADAR SITE
  ⍝---------------------INPUT -----------------------------------+
  ⍝
  ⍝ THIS PROGRAM PROMPTS THE FOLLOWING INPUTS:
  ⍝
  ⍝ 1. THE TIME OF THE TIME STEP OF THE SIMULATION (IN SEC).
  ⍝
  ⍝ 2. THE LOCATION (X,Y) OF THE MISSILE RADAR SITE (IN N.M).
  ⍝
  ⍝ 3. THE DETECT FILE (DETECTS1 OR 2 ETC) GIVEN BY THE 'FDETECT'
  ⍝    WORKSPACE. THIS RADAR SITE IS SUPPOSED TO SUPPORT THE
  ⍝    INTERCEPTOR MISSILE OR A/C.
  ⍝
  ⍝ 4. THE MAXIMUM RANGE OF THE INTERCEPTOR MISSILE (IN N.M)
  ⍝
  ⍝ 5. THE SPEED OF THE INTERCEPTOR MISSILE (IN KNOTS)
  ⍝
  ⍝ 6. THE FLIGHT TARGET DATA (TARGET1 OR 2 ETC) GIVEN BY THE
  ⍝    'MOVEMENT' WORKSPACE.
  ⍝
  ⍝    NOTE: THE ORDER OF ENTERING THE FLIGHT DATA OF THE TARGETS
  ⍝    ----  MUST BE IN ASCENT ORDER. I.E: YOU MUST ENTER THE
  ⍝          TARGET1 FIRST THE TARGET2 SECOND AND SO ON UNTIL
  ⍝          ALL TARGETS ARE ENTERED IN THE PROGRAM.
  ⍝
```

```
[36]  A1←A1,0 ⋄ →L13
[37] L12:MALT←MALT[X←SX[K];Y←SY[K]] ⍝⋄ X ⋄ Y ⋄ MALT ⋄ ALT
[38]  →(MALT≠¯1)/L9 ⍝ CHECK IF THE TGT IS INSIDE THE MAX RANGE OF SITE.
[39]  A1←A1,0 ⋄ →L13
[40] L9:→(ALT>MALT)/L11 ⍝- CHECK IF THE ALT OF THE TGT IS HIGHER THAN
[41] ⍝-------------------- THE RADAR SITE ALTITUDE.
[42]  A1←A1,0 ⋄ →L13
[43] L11:A1←A1,1
[44] L13:→(K<P)/L10
[45]  ''
[46]  'IF YOU HAVE AN ANOTHER TARGET ENTER  0'
[47]  'IF YOU LIKE TO EXIT           ENTER  1'
[48]  KK←⎕
[49]  →(KK=0,KK=1,KK≥2)/L4,L7,L6
[50] L6:ERROR ⋄ →L7
[51] L7:A2←((ρD),(M←1↑(D[⍒D])))ρ0
[52]  I←1
[53] L8:A2[I;]←((D[I]↑A1),(M-D[I])ρ0) ⋄ A1←D[I]↓A1 ⋄ I←I+1
[54]  →(I≤(ρD))/L8
[55]  A3←(((M,1)ρ⍳M),⍉A2)
[56]  A3
[57]  '' ⋄ ''
[58]  '----------------------------------------------------'
[59]  '      THE OUTPUT IS STORED UNDER THE VARIABLE A3'
[60]  '----------------------------------------------------'
    ∇


    ∇ INTER;A;ANS;D;DF;DF1;DIR;I;K;L;M;MM;Q;RMAX;RO;RO1;SPEED;T;TGT;TI;V1;V2;VR;
W;W2;X0;X1;XR;XS;XT;AC;TEST;AA;DIST
[1]  ⍝ ⍝--------------------- PURPOSE ------------------------------------+
[2]  ⍝
[3]  ⍝  THIS PROGRAM IS USED TO CALCULATE THE INTERCEPTION STATE MATRIX
[4]  ⍝  FOR EACH RADAR SITE
[5]  ⍝---------------------INPUT -------------------------------------+
[6]  ⍝
[7]  ⍝ THIS PROGRAM PROMPTS THE FOLLOWING INPUTS:
[8]  ⍝
[9]  ⍝ 1. THE TIME OF THE TIME STEP OF THE SIMULATION (IN SEC).
[10] ⍝
[11] ⍝ 2. THE LOCATION (X,Y) OF THE MISSILE RADAR SITE (IN N.M).
[12] ⍝
[13] ⍝ 3. THE DETECT FILE (DETECTS1 OR 2 ETC) GIVEN BY THE 'FDETECT'
[14] ⍝    WORKSPACE. THIS RADAR SITE IS SUPPOSED TO SUPPORT THE
[15] ⍝    INTERCEPTOR MISSILE OR A/C.
[16] ⍝
[17] ⍝ 4. THE MAXIMUM RANGE OF THE INTERCEPTOR MISSILE (IN N.M)
[18] ⍝
[19] ⍝ 5. THE SPEED OF THE INTERCEPTOR MISSILE (IN KNOTS)
[20] ⍝
[21] ⍝ 6. THE FLIGHT TARGET DATA (TARGET1 OR 2 ETC) GIVEN BY THE
[22] ⍝    'MOVEMENT' WORKSPACE.
[23] ⍝
[24] ⍝    NOTE: THE ORDER OF ENTERING THE FLIGHT DATA OF THE TARGETS
[25] ⍝    ----  MUST BE IN ASCENT ORDER. I.E: YOU MUST ENTER THE
[26] ⍝          TARGET1 FIRST THE TARGET2 SECOND AND SO ON UNTIL
[27] ⍝          ALL TARGETS ARE ENTERED IN THE PROGRAM.
[28] ⍝
```

```
⍝----- ANGLE BETWEEN TARGET AND INTERCEPTOR = 0 DEGREE------
L3:VD←V1+V2
⍝ 'TIME FOR INTERCEPTION (IN MIN) =',⍕T←(D÷VD)×60
⍝ 'DISTANCE FOR TARGET = ',⍕T×(V1÷60)
⍝ 'DISTANCE FOR INTERCEPTOR =',⍕T×(V2÷60)
 Q←T×(V2÷60)
L10:Q ⋄ →(Q≤RMAX)/L11
 A←A,0,0 ⋄ DIST←DIST,0 ⋄ →LP1
L11:DIST←DIST,(LD) ⍝ CREATES THE DISTANCE VECTOR
 A←A,1,⌈((T×60)÷TI) ⋄ →LP1
END:A1←((⍴DF),2)⍴A ⋄ DIST←((⍴DF),1)⍴DIST
 AA←AA,A1,DIST ⋄ A1←AA
 'IF YOU HAVE ANOTHER TARGET ENTER  0'
 'TO EXIT ENTER                     1'
 ANS←⎕
 →(ANS=0)/L14
 '------------------------------------------------------------'
 '      THE OUTPUT IS STORED UNDER THE VARIABLE A1'
 '------------------------------------------------------------'
∇
```

```
∇ PRIORITY;TGT1;TGT2;AN;A;A1;K;T;I;P;P1;DIR1;DIR2;DIR3;ALT1;V;M;TGT;DEGREE
⍝
⍝---------------------- PURPOSE -----------------------------------→
⍝
⍝  THIS PROGRAM IS USED TO FIND OUT THE PRIORITY OF THE TARGETS
⍝  TO BE KILLED BY THE ENEMY RADAR SITES, AS FAR AS, HOW DENGEROUS
⍝  THE TARGET IS, IS CONCERNED.
⍝
⍝---------------------- INPUTS ------------------------------------→
⍝
⍝  THIS PROGRAM PROMPTS THREE INPUTS:
⍝
⍝  1. THE CRITICAL COURSE THAT THE TARGET FLIGHT COURSES WILL BE
⍝     COMPARED.
⍝
⍝  2. THE TARGET FLIGHT DATA (TARGET1,2 ETC) GIVEN BY THE 'MOVEMENT'
⍝     PROGRAM.
⍝
⍝--------------------- OUTPUT -------------------------------------→
⍝
⍝  THE OUTPUT IS A (M N+1) MATRIX WHERE:
⍝
⍝  M = THE NUMBER OF TIME STEPS
⍝  N = THE NUMPER OF TARGETS
⍝  THE FIRST COLUMN IS THE TIME STEPS
⍝
⍝-------------------- MAIN PROGRAM --------------------------------→
⍝
 TGT1←TGT2←DIR1←DIR3←ALT1←V←⍳0 ⋄ P←0
 'ENTER THE CRITICAL COURSE'
 DEGREE←⎕ ⋄ ''
L1:'ENTER THE TARGET FLIGHT DATA (TARGET1,2,ETC)'
 TGT←⎕ ⋄ P←P+1 ⋄ V←V,⍴TGT[1;]
 TGT1←TGT1,TGT[4;]
 TGT2←TGT2,TGT[5;]
 K←⍴(TGT[1;])
L4:'IF YOU HAVE ANOTHER TARGET ENTER  0'
 ' OTHERWISE ENTER                  1'
 AN←⎕
 →((AN=0),(AN=1),(AN≥2))/L1,L2,L3
L3:ERROR ⋄ →L4
L2:A←A1←(P,(M←(1↑(V[⍒V]))))⍴0 ⋄ I←1
L6:A[I;]←((V[I])↑TGT1),(M−V[I])⍴0 ⋄ TGT1←(V[I])↓TGT1
 A1[I;]←((V[I])↑TGT2),(M−V[I])⍴0 ⋄ TGT2←(V[I])↓TGT2 ⋄ I←I+1
```

```
 →(I≤P)/L6
 K←1
L7:I←1 ⋄ DIR1←ALT1←⍳0
L5:DIR1←DIR1,A1[I;][K]
 ALT1←ALT1,A[I;][K]
 I←I+1
 →(I≤P)/L5
 K←K+1
 T←P1←0 ⋄ DIR1←(P)⍴DIR1
L8:T←T+1
 →(DIR1[T]≠0)/L9
 DIR1[T]←1000 ⋄ P1←P1+1
L9:→(T<(⍴DIR1))/L8
L9:DIR2←⍋(|DEGREE-DIR1) ⋄ DIR2[⍳P1]←0
 DIR3←DIR3,⍉DIR2
 →(K≤M)/L7
 A3←((M,1)⍴⍳M),(M,P)⍴DIR3
 A3
 '-------------------------------------------------------------'
 '        THE OUTPUT IS STORED UNDER THE VARIABLE A3'
 '-------------------------------------------------------------'
    ∇
```

APPENDIX F

This Appendix contains all the computer programs of the "AIRMODEL" workspace.

```
    ∇ MAIN;CMD;WTH;STEP;CAPP2;TK1;ADSITES;AISITES;NSITES;SDD2;P;MCAPP2;I1;I2;I3;
R1;R2;R3;T;TIMES
[1]  ⍝
[2]  ⍝--------------------- PURPOSE ---------------------------------+
[3]  ⍝
[4]  ⍝  THE PURPOSE OF MAIN PROGRAM IS TO COMBINE THE DATA BASE WITH
[5]  ⍝  THE FUNCTIONS USED TO CALCULATE THE ATTRITION RATE OF THE
[6]  ⍝  AIRCRAFT FORMATION.
[7]  ⍝
[8]  ⍝--------------------- INPUT -----------------------------------+
[9]  ⍝
[10] ⍝  THE MAIN PROGRAM PROMPTS THE FOLLWING INPUTS:
[11] ⍝
[12] ⍝   1. RL:      THE SEED FOR THE RANDOM NUMBER FUNCTION.
[13] ⍝   2. TIMES:   THE NUMBER OF TIMES THAT THE PROGRAM WILL RUN.
[14] ⍝   3. NSITES:  THE NUMBER OF THE RADAR SITES.
[15] ⍝   4. DS2:     THE DETECTION MATRIX OF EACH RADAR SITE (GIVEN BY
[16] ⍝               THE FDETECT PROGRAM).
[17] ⍝   5. IS2:     THE INTERCEPTION MATRIX OF EACH RADAR SITE (GIVEN
[18] ⍝               .BY THE INTERCPT PROGRAM).
[19] ⍝   6. TGT:     THE NUMBER OF AIRCRAFT THAT EACH FORMATION HAS.
[20] ⍝   7. CAP2:    THE NUMBER OF TARGET THAT EACH RADAR SITE CAN
[21] ⍝               ENGAGE.
[22] ⍝   8. MCAP2:   THE NUMBER OF MISSILES EACH RADAR SITE HAS.
[23] ⍝   9. PKM:     THE PROBABILITY OF KILL MATRIX.
[24] ⍝  10. IFF:     THE DECISION IF IFF EXISTS.
[25] ⍝  11. IFFWORK:THE PROBABILITY THAT IFF WORKS.
[26] ⍝  12. IFFFOF: THE DECISION IF THE TARGET IS FRIEND OR FOE, GIVEN
[27] ⍝               THAT IFF DOES NOT WORK.
[28] ⍝  13. IFFCOR: THE PROBABILITY THAT IDENTIFICATION IS CORECT,GIVEN
[29] ⍝               THAT IFF WORKS.
[30] ⍝  14. ECM:     THE ELECTRONIC COUNTERMEASURE MEANS MATRIX FOR THE
[31] ⍝               ECM FUNCTION GIVEN BY THE ECM MODEL.
[32] ⍝  15. CMD:     THE DECISION FOR THE COMMAND AND CONTROL MODEL.
[33] ⍝  16. AUTO:    THE NUMBER OF AIRCRAFTS ABOVE OF WHICH THE RADAR
[34] ⍝               SITES OPERATE AUTONOMOUSLLY.
[35] ⍝  17. PR:      THE PRIORITY MATRIX GIVEN BY THE PRIORITY MODEL.
[36] ⍝  18. WTH:     THE DESITION FOR GOOD OR BAD RADAR SITE OPERATION.
[37] ⍝  19. LBR:     THE FACTOR THAT THE PROBABILITY OF AQUASITION
[38] ⍝               BREAKINK WILL INCREASE, GIVEN THAT THE OPERATION
[39] ⍝               OF THE RADAR SITES IS DISGRADED.
[40] ⍝  20. ETSF:    THE FACTOR THAT THE EVENT TIME STEPS MATRIX WILL
[41] ⍝               INCREASE ,GIVEN THAT THE OPERATION OF RADAR SITES
[42] ⍝               IS DISGRADED.
[43] ⍝  21. TSTEP1:  THE EVENT TIME STEPS MATRIX.
[44] ⍝
[45] ⍝--------------------- OUTPUT ----------------------------------+
[46] ⍝
[47] ⍝  THE MAIN PROGRAM GIVES THE FOLLOWING OUTPUTS:
[48] ⍝
[49] ⍝   1. A SUMMARY OF THE USED SENARIO.
[50] ⍝   2. IN DETAILS ATTRITION MATRIX.
[51] ⍝   3. REMAIN MISSILES PER RADAR SITE.
[52] ⍝   4. THE NUMBER OF TARGETS WHICH ARE KILLED BUT NO ASSESSED.
```

```
⍝   5. THE NUMBER OF KILLED TARGETS.
⍝
⍝---------------------- COMMENTS ----------------------------------→
⍝
⍝  THE MAIN PROGRAM CALLS THE FOLLWING PROGRAMS:
⍝
⍝   1. SITE
⍝
⍝---------------------- MAIN PROGRAM ------------------------------→
⍝
 TGTSTAT←⍳0
 'ENTER THE NEW SEED'
 ⎕RL←⎕
 'ENTER THE NUMBER OF TIMES THE PROGRAM TO RUN'
 TIMES←⎕
 T←0
LP3:→(T≥TIMES)/TELOS
 T←T+1
 ADSITES←AISITES←⍳0
⍝--------------------- RADAR SITES DATA ---------------------------→
 ''
 'ENTER THE NUMBER OF THE RADAR SITES'
 NSITES←4 ⋄ '' ⋄ TESTMCAP←⍳NSITES
 P←0
PP2:P←P+1
 →(P>NSITES)/PP1
 'ENTER THE DETECTION MATRIX OF THE SITES',(⍕P)
 DDS2←⎕ ⋄ ADSITES←ADSITES,(,DDS2) ⋄ →PP2
PP1:DDS2←(NSITES,(ρDDS2[;1]),(ρDDS2[1;]))ρADSITES
 STGT←((NSITES),((ρDDS2[1;1;])-1))ρ(⍳((ρDDS2[1;1;])-1))
 TESTINT←((NSITES),((ρDDS2[1;1;])-1))ρ1
 P←0
PP3:P←P+1
 →(P>NSITES)/PP4
 'ENTER THE INTERCEPTION MATRIX FOR THE SITES',(⍕P)
 IS2←⎕ ⋄ AISITES←AISITES,(,IS2) ⋄ →PP3
PP4:MIS2←(NSITES,(ρIS2[;1]),(ρIS2[1;]))ρAISITES
 I1←2 ⋄ I2←3 ⋄ I3←4 ⋄ R1←R2←R3←⍳0
II1:→((ρR1)≥((ρDDS2[1;1;])-1))/II2
 R1←R1,I1 ⋄ R2←R2,I2 ⋄ R3←R3,I3
 I1←I1+3 ⋄ I2←I2+3 ⋄ I3←I3+3 ⋄ →II1
II2:SEF←MIS2[;;R1] ⋄ STS←MIS2[;;R2] ⋄ STD←MIS2[;;R3]
ER9:'ENTER THE VECTOR NUMBER OF A/C THAT EACH TARGET HAS'
 TGT←⎕
 →((ρTGT)=((ρDDS2[1;1;])-1))/ER8
 ERROR ⋄ →ER9
ER8:TGT1←TGT ⋄ ALLTGT←⍳(ρTGT)
PP6:'ENTER THE NUMBER OF TGTS THAT THE SITE CAN ENGAGE'
 CAP2←⎕ ⋄ CAPP2←CAP2 ⋄ ''
 →((ρCAP2)=NSITES)/PP7
 ERROR ⋄ →PP6
PP7:'ENTER THE NUMBER OF MISSILE THAT EACH SITE HAS (VECTOR)'
 MCAP2←⎕ ⋄ MCAPP2←MCAP2 ⋄ ''
 →((ρMCAP2)=NSITES)/PP8
 ERROR ⋄ →PP7
PP8:'ENTER THE PK MATRIX OF THE MISSILE FUNCTION'
 PKM←⎕ ⋄ ''
ER2:'IF YOU LIKE IFF IDIFICATION ENTER    1'
 'OTHERWISE ENTER                         0'
 IFF←1 ⋄ ''
 →((IFF=0),(IFF=1))/ER3,ER10
 ERROR ⋄ →ER2
ER10:'ENTER THE PROBABILITY THAT THE IFF WORKS'
 IFFWORK←⎕ ⋄ ''
 →(IFFWORK≠0)/DD1
ER1:'IF YOU LIKE ALL TGTS TO BE FRIENDS(IFF NOT WORK) ENTER  1'
 ' IF YOU LIKE ALL TGTS TO BE FOE  ENTER                    0'
 IFFFOF←⎕ ⋄ ''
 →((IFFFOF=0),(IFFFOF=1))/ER3
```

```
 ERROR ◊ →ER1
DD1:'ENTER THE PROB. THAT THE IDIFICATION IS CORRECT/IFF WORKS)'
 IFFCOR←⎕ ◊ ''
ER3:'ENTER THE ECM MATRIX OF ECM FUNCTION'
 ECM←⎕ ◊ ''
TT1:'IF YOU LIKE COMMAND CONTROL MODEL ENTER   1'
 'OTHETWISE ENTER                              0'
 CMD←⎕ ◊ ''
 →(CMD=0)/ER4
 'ENTER THE NUMBER OF AIRCRAFTS ABOVE OF WHICH THE RADAR'
 'SITES OPERATES AUTONOMOUSLY'
 AUTO←⎕
ER4:'ENTER THE PRIORITY MATRIX'
 PR←⎕
ER44:'IF YOU LIKE GOOD RADAR SITE OPPERATION ENTER  1'
 'IF YOU LIKE DISGRADED RADAR SITE OPPERATION ENTER   0'
 WTH←1 ◊ ''
 →((WTH=0),(WTH=1))/ER5,ER55
 ERROR ◊ →ER44
ER5:'ENTER THE INCEASE FACTOR FOR AQUASITION BREAK PROBABILITY'
 LBR←⎕ ◊ ''
 'ENTER THE INCREASE FACTOR FOR EVENTS TIME STEPS MATRIX'
 ETSF←⎕ ◊ ''
 TSTEP1←TSTEP←TSTEP1+⌊TSTEP1×(ETSF) ⍝ DISGRADED OPPERATION
 ECM[;4]←ECM[;4]+ECM[;4]×LBR
ER55:'ENTER THE EVENTS TIME STEPS MATRIX(ID,TRACK,FIRE,ASESS)'
 TSTEP←⎕ ◊ '' ◊ TSTEP1←TSTEP←((⍴TGT),(NSITES),4)⍴,TSTEP
 DS2←DDS2 ⍝ DS2=THE DETECTION MATRIX OF SITE 2 + 10 ROWS
 ASS←0 ◊ TFERROR←1
 AS2←((NSITES,((⍴DS2[1;;1])+10),1)⍴(⍳((⍴DS2[1;;1])+10))),((NSITES,((⍴DS2[1
;;1])+10),(⍴ALLTGT))⍴0)
⍝------------- TIME STEP LOOP ---------------------------------+
 I←0
ALP2:→(I>1)/END
LP2:→(I≥((⍴DS2[1;;1])))/END
 I←I+1 ◊ '' ◊ 'I=',⍕I
⍝------------- RADAR SITES LOOP ------------------------------+
 SS←0
LP1:→(SS≥NSITES)/LP2
 SS←SS+1
⍝ →(MCAP2[SS]>0)/LLL1
⍝ →(I>TESTMCAP[SS])/LP1
 '...SITE = ',⍕SS
 SS SITE I
 →LP1
END: ⍝-----------END OF THE SIMULATION-----------------------------+
 '                        SENARIO'
 '                        -------'
 'NUMBER OF TARGET PER FORMATION = ',⍕TGT1
 'TARGET CAPACITY PER MISSILE SITE = ',(⍕CAPP2)
 'MISSILE CAPACITY  PER MISSILE SITE= ',(⍕MCAPP2)
 'IFF = ',(⍕IFF)
 'PROB THAT IFF WORKS = ',(⍕IFFWORK)
 'PROB THAT IDENTIF. IS CORRECT/IFF WORKS = ',(⍕IFFCOR)
 'FRIEND/ENEMY IF IFF DOES NOT WORKS = ',(⍕IFFFOF)
 'COMMAND CONTROL MODEL = ',(⍕CMD)
 'RADAR OPPERATION(GOOD/BAD) = ',(⍕WTH)
 'ECM MATRIX = '
 ECM
 'PK MATRIX = '
 PKM
 ' --------------- RESULT -------------------------------------'
⍝ ''
 →(IFF=0)/AS1
 'TGT 2 HAS BE ENGEGED = ',(⍕(TFERROR-1))
```

```
AS1:TK1←⍉(((⍴TK)÷3),3)⍴TK
 'IN DETAILS ATTRITION MATRIX:'
 'MISSILE SITE = ',(⍕TK1[1;])
 'TIME STEP    = ',(⍕TK1[2;])
 'KILLED TGT   = ',(⍕TK1[3;])
 TGTSTAT←TGTSTAT,(TGT1−TGT)
 →LP3
TELOS:TGTSTAT←⍉(T,(⍴TGT1))⍴TGTSTAT
 'REMAIN MISSILES =',⍕MCAP2
 'NO ASSESS TGT = ',⍕ASS
 'KILLED TGTS (TGTSTAT)= ' ⋄ ⍝,(⍕(,TGTSTAT))
 TGTSTAT
⍝------------ ERASE GLOBAL VARIABLES ----------------------------+
 QQ←⎕EX 'STGT TESTINT IS2 SEF STS STD TGT TGT1 ALLTGT CAP2 MCAP2 IFF PR TS
TEP TSTEP1 DS2 RD RN NT PK I SS INT CHECK ISITE TK TK1 ASS ECM TFERROR TK1'
    ∇


    ∇ SS SITE I;EV;FF;ID;II;K;MT;NN;NT;Z;NT1;P;PRIOR;TT;Z;EV;TEST;AM;PKC
 ⍝
 ⍝-------------------- PURPOSE -------------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED TO CALCULATE THE ATTRITION RATE OF THE
 ⍝  ATTACKING AICRAFT FORMATIONS AGAINST GROUND TARGETS
 ⍝
 ⍝-------------------- INPUT ---------------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS CALLED BY THE MAIN PROGRAM AND USES THE FOLLWING
 ⍝  INPUTS:
 ⍝    1. THE LEFT ARGUMENT IS THE NUMBER OF RARAR SITE
 ⍝    2. THE RIGHT ARGUMENT IS THE TIME STEP
 ⍝    3. SOME OTHER GLOBAL VARIABLES
 ⍝
 ⍝-------------------- OUTPUT --------------------------------------+
 ⍝
 ⍝  THIS FUNCTION CALLS THE IDIF, TRACK, FIRE, ASSES,INTER ,RANDOM
 ⍝  AND PKILL FUNCTIONS IN ORDER TO PERFORM THE FUTURE EVENTS AND
 ⍝  CALCULATE THE ATRITION RATE.
 ⍝
 ⍝-------------------- MAIN PROGRAM --------------------------------+
 ⍝
 ⍝-------------------- INITIALIZE ----------------------------------+
 →(I>1)/CONT
 NT1←0 ⋄ TK←⍳0 ⍝TIME/KILL VECTOR
CONT:ISITE←I,SS ⍝CONTAINS THE TIME STEP + THE NUMBER OF SITE CALLED
 →((+/NN←1↓AS2[SS;I;])=0)/L4 ⍝CHECK IF THERE IS AN EVENT
 P←0 ⍝⋄ 'THERE IS EVENTS' ⋄ 'NN=',⍕NN
LP1:→(P≥(⍴NN))/L7 ⍝⋄ LOOP FOR EVENTS
 P←P+1 ⍝⋄ 'P=',⍕P
 EV←NN[P]
 →(EV=0)/LP1 ⍝ THE END OF THE EVENTS  ⍝ 'EVENT=',⍕EV
 EV←EV−⍎(⍕SS),'00' ⍝ FORM THE EVENTS ⋄ 'EV=',⍕EV
 →((EV≤19),(EV≤29),(EV≤39),(EV≤49),(EV≤59))/EV1,EV2,EV3,EV4,EV5
EV1:NT←EV−10 ⋄ TT←ISITE TRACK NT ⋄ →LP1 ⍝ CALL THE TRACK FUNCTION
EV2:NT←EV−20 ⋄ FF←ISITE FIRE NT ⋄ →LP1 ⍝ CALL THE FIRE FUNCTION
EV3:NT←EV−30 ⋄ INT←ISITE INTER NT ⋄ →LP1 ⍝ CALL THE INTER FUNCTION
EV4:NT←EV−40 ⋄ AM←ISITE ASSES NT ⍝ CALL THE ASSES FUNCTION
 ⍝
 ⍝------------------ RESULT OF INTERCEPT --------------------------+
 →(TGT[NT]>0)/TT1
 ⍝ 'IF ALL A/C OF FORMATION ARE KILLED THE TGT GO OUT OF SIMULATION'
 →(((⍴DS2[SS;;(NT+1)])−(I+ASES))≥0)/TT2 ⍝ NO DETECTION STOP PROCCESS
 →LP1
 DS2[SS;((⍳((⍴DS2[SS;;(NT+1)])−(I+ASES)))+I);(NT+1)]←0 ⋄ →LP1
 ⍝ ALL DETECTION COLUMN FOR THIS TGT BECAMES ZERO
TT1:→(MCAP2[SS]=0)/LP1 ⍝ NO REMAIN MISSILE  SITE OUT OF SIMULATION
 →(TESTINT[SS;NT]=0)/LP1
 ⍝ IF NO INTERCEPT NO KILL COUNT
```

```
⍝------------- PK FUNCTION ----------------------------------------+
 PK←PKM PKILL SS,STD[SS;I;NT] ⍝ CALL THE PK FUNCTION
⍝ 'PK = ',⍕PK ⋄ ⍝'R= ',⍕STD[SS;I;NT]
 RN←RANDOM ⍝⋄ 'RN = ',⍕RN  ⍝ CALL THE RANDOM FUNCTION
 →(RN>PK)/RESS1
 149 ⎕POKE 161 ⋄ 'KILL !!! ONE TARGET ',(⍕NT) ⋄ 26 ⎕POKE 161
 TGT[NT]←TGT[NT]-1 ⋄ TK←TK,SS,I,NT
⍝KILL SUBSRUCT ONE TGT FROM FORMATION
 MCAP2[SS]←MCAP2[SS]-1
⍝KILL SUBSTUCT ONE MISSILE FROM MISSILE STOCK
 TSTEP[NT;SS;]←TSTEP1[NT;SS;]
 →(TGT[NT]≤0)/TT2
 →LP1 ⍝ IF ALL A/C OF FORMATION ARE KILLED THE TGT GO OUT OF SIM.
TT2:DS2[SS;((⍳((⍴DS2[SS;;(NT+1)])-I))+I);(NT+1)]←0 ⋄ →LP1
RESS1:MCAP2[SS]←MCAP2[SS]-1 ⍝ NO KILL SUBSTRUCT ONE MISSILE
 TSTEP[NT;SS;]←TSTEP1[NT;SS;] ⋄ →LP1
⍝
⍝------------------ RESULT OF ASSESS ------------------------------+
EV5:
 NT←EV-50
ES1: ⍝'THE TGT ',(⍕NT),' ENTER AGAIN THE DETECTION LIST'
⍝ INITIALIZE AGAIN THE INTERCEPTION PROCCESS
 STGT[SS;NT]←NT ⋄ ALLTGT[NT]←NT ⋄ CAP2[SS]←CAP2[SS]+1
⍝
⍝------------------- DETECTION EVENT ------------------------------+
L4:→L8 ⍝⋄ 'NO CURRENT EVENTS'
L7: ⍝'END OF EVENTS'
L8:Z←1↓DS2[SS;I;]
 →(CAP2[SS]>0)/L3 ⍝⋄--CAP2ACITY CONTITON
 →END ⍝⋄ 'THE SITE2 IS FULL=',⍕CAP2[SS]
L3:MT←+/Z
 →((MT=0),(MT=1),(MT≥2))/L0,L1,L2
L0:→END ⍝'NO TARGET IN TARGET DETECTION LIST'
⍝---------- CASE THAT RADAR SITE CAN SEE ONLY ONE TGT ------------+
L1:NT←Z⍳1 ⍝⋄ 'TGT TO BE ID1=',⍕NT
 →(Z[NT]≠0)/D1
 →END ⍝ ⋄ 'THE TGT=',(⍕NT),' IS NOT IN DETECTION LIST'
D1:→(STGT[SS;NT]≠0)/AL1
 →END ⍝⋄ 'THE  TGT ALLREADY ID1 =',⍕NT ⋄ →END
⍝ ------------COMMAND AND CONTROL MODEL--------------------------+
AL1:→(CMD=0)/L5
 →(ALLTGT[NT]≠0)/L5
 →(TGT[NT]>AUTO)/L5 ⍝ NUMBER OF TGT GREATER THAN ONE
 →END ⍝'THE TGT',(⍕NT),' IS ALLREADY ENGAGED BY AN OTHER  SITE'
L5:CAP2[SS]←CAP2[SS]-1 ⋄ STGT[SS;NT]←0 ⋄ ALLTGT[NT]←0
 ID←ISITE IDIF NT ⋄ →END ⍝CALL THE IDIF FUNCTION
⍝---------- CASE THAT RADAR SITE CAN SEE TWO OR MORE TGT ---------+
L2:PRIOR←1↓PR[I;]
LP2:NT←1↑PRIOR ⋄ PRIOR←1↓PRIOR
 →(NT=0)/END
 →(Z[NT]≠0)/D2
 →LP2 ⍝ 'THE TGT=',(⍕NT),' IS NOT IN DETECTION LIST' ⋄ →LP2
D2:→(STGT[SS;NT]≠0)/AL2
 →LP2 ⍝ 'TARGET ALLREADY ID' ⋄ 'THE TGT VECTOR=',⍕STGT[SS;NT]
⍝----------- COMMAND AND CONTROL MODEL----------------------------+
AL2:→(CMD=0)/L6
 →(ALLTGT[NT]≠0)/L6
 →(TGT[NT]>AUTO)/L6 ⍝ IF THE NUMBER OF TGT GREATER THAN VAR. AUTO
⍝  THEN THIS TGT IS ENGANGED BY MORE THAN ONE RADAR SITE
 →LP2 ⍝'THE TGT',(⍕NT),' IS ALLREADY ENGAGED BY AN OTHER SITE'
L6:CAP2[SS]←CAP2[SS]-1 ⋄ STGT[SS;NT]←0 ⋄ ALLTGT[NT]←0
⍝⋄ 'THE TGT VECT=',(⍕STGT[SS;NT])
 ID←ISITE IDIF NT ⍝⋄ 'THE ID2 TGT=',⍕NT
 →LP2
END:
∇
```

```
    ∇ ID←ISITE IDIF R;CHECK;II;RN;RD;IDD
 ⍝
 ⍝-------------------- PURPOSE ------------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED BY THE SITE FUNCTION TO PERFORM THE
 ⍝  IDINTIFICATION OF THE TARGETS.
 ⍝
 ⍝------------------- INPUTS --------------------------------------+
 ⍝
 ⍝  1. THE LEFT ARGUMENT IS A VECTOR WHOSE FIRST ELEMENT IS THE
 ⍝     NUMBER OF RADAR SITE AND THE SECOND ONE IS THE TIME STEP.
 ⍝  2. THE RIGHT ARGUMENT IS THE NUMBER OF TARGET.
 ⍝  3. THIS FUNCTION USES SOME OTHER GLOBAL VARIABLES.
 ⍝
 ⍝------------------- OUTPUT --------------------------------------+
 ⍝
 ⍝  THE OUTPUT IS THE  FUTURE IDINTIFICATION EVENT
 ⍝
 ⍝------------------- MAIN PROGRAM --------------------------------+
 ⍝
  I←ISITE[1] ⋄ RD←ISITE[2] ⋄ IDD←TSTEP[R;RD;1]
 ⍝ 'TGT=',⍕R ⋄ 'IDD=',⍕IDD
  →(MCAP2[RD]>0)/TT1 ⍝ NO MISSILE NO FUTURE EVENT
  →TT2
TT1: ⍝'TARGET TO BE ID= ',⍕R
  →(IDD<((⍴(DS2[RD;;R+1]))-I))/TT3 ⍝SIMULATION OF ID STOP WHEN THE
 ⍝ REMAINING TIME STEPS ARE LESS THAN THE NUMBER THAT THE ID PROCESS
 ⍝NEEDS
  ID←0 ⋄ DS2[RD;(⍳1↑((⍴(DS2[RD;;(R+1)]))-I))+I;R+1]←0 ⋄ →END
TT3:CHECK←×/(,DS2[RD;;R+1])[I+⍳IDD] ⍝CHECK IF THERE IS DETECTION
 ⍝ 'CHECK OF ID=',⍕CHECK
  →(CHECK≠0)/L6
 ⍝ 'NO DETECTION ... NO IDIFIC.'
  DS2[RD;(I-1)+⍳(IDD+1);R+1]←0
TT2:STGT[RD;R]←R ⋄ ALLTGT[R]←R
 ⍝ 'TARGET ',(⍕R),' AGAIN FOR DETECTION'
  ID←0 ⋄ CAP2[RD]←CAP2[RD]+1 ⋄ →END
 ⍝---------------- TEST FOR IDIDIFICATION -------------------------+
L6:→(IFF=0)/L1 ⍝ IFF NO IFF IS APLLIED ALL TARGET ARE ENEMIES
  RN←RANDOM ⍝⋄ 'RN=',⍕RN
  →((RN>IFFWORK),(RN≤IFFWORK))/L3,L4
L3:→(IFFFOF=0)/L1 ⋄ ⍝ IF IFFFOF = 0 ALL TARGETS ARE ENEMIES
 ⍝ IF IFFFOF = 1 ALL TARGETS ARE FRIENDS
  ID←0 ⋄ STGT[RD;R]←R ⋄ ALLTGT[R]←R ⋄ CAP2[RD]←CAP2[RD]+1 ⋄ →END
 ⍝⋄ 'TARGET',(⍕R),'ENTER AGAIN' ⋄ →END
L4:RN←RANDOM ⍝⋄ 'RN=',⍕RN
  →((RN≥IFFCOR),(RN≤IFFCOR))/L7,L8
 ⍝ IF IFF IS WRONG THE FRIEND TARGET IS ENEMY, AND THE ENEMY TARGET
 ⍝ IS FRIEND,IF THE IFF IS CORRECT THE OPPOSITE.
L7:→(R=2)/L9 ⍝ NUMBER 2 TARGET IS FRIEND  BY THE SENARIO
 ⍝ 'TARGET ',(⍕R),' ENTER AGAIN'
  ID←0 ⋄ STGT[RD;R]←R ⋄ ALLTGT[R]←R ⋄ CAP2[RD]←CAP2[RD]+1 ⋄ →END
L9:TFERROR←TFERROR+1 ⋄ →L1 ⍝ NUMBER A FRIEND TARGET IS ENGAGED
L8:→(R≠2)/L1 ⍝ NUMBER 2 TARGET IS FRIEND  BY THE SENARIO
 ⍝ 'TARGET ',(⍕R),' ENTER AGAIN'
  ID←0 ⋄ STGT[RD;R]←R ⋄ ALLTGT[R]←R ⋄ CAP2[RD]←CAP2[RD]+1 ⋄ →END
L1:II←(,AS2[RD;(I+IDD);])⍳0 ⍝FINDS WHICH ELEMENT AS2 MATRIX IS ZERO
  AS2[RD;(I+IDD);II]←⍎(⍕RD),'1',(⍕R) ⍝ GENERATE EVENTS(1=IDIFIC)
  ID←AS2[RD;I+IDD;]
 ⍝ 'THE EVENTS ROW FOR IDIT IS = ',⍕ID←AS2[RD;I+IDD;]
END:
    ∇
```

```
∇ TT←ISITE TRACK T;CHECK;IIRD;TR1
 ⍝
 ⍝------------------------ PURPOSE --------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED BY THE SITE FUNCTION TO PERFORM THE
 ⍝  TRACK TARGET EVENT.
 ⍝
 ⍝------------------------ INPUT ----------------------------------+
 ⍝
 ⍝  1. THE LEFT ARGUMENT IS A VECTOR WHOSE FIRST ELEMENT IS THE
 ⍝     RADAR SITE NUMBER AND THE SECOND ONE IS THE TIME STEP.
 ⍝  2. THE RIGHT ARGUMENT IS THE NUMBER OF TARGET.
 ⍝  3. THIS FUNCTION USES SOME OTHER GLOBAL VARIABLES.
 ⍝
 ⍝------------------------ OUTPUT ---------------------------------+
 ⍝
 ⍝  THE OUTPUT IS THE FUTURE TRACK EVENT.
 ⍝
 ⍝------------------------ MAIN PROGRAM ---------------------------+
 ⍝
  I←ISITE[1] ⋄ RD←ISITE[2] ⋄ TR1←TSTEP[T;RD;2] ⋄ ⍝ 'TR=',⍕TR1 ⋄ 'TGT=',⍕T
  →(MCAP2[RD]>0)/L2
  →L3
 ⍝----------------- ECM MODEL ------------------------------------+
 L2:→(ECM[T;5]=0)/L11 ⍝ ECM DOES NOT EXIST
  RN←RANDOM
  →(RN>ECM[T;5])/L12 ⍝ ECM DOES NOT WORK
  PK←ECM PKILL T,STD[RD;I;T]
  RN←RANDOM
  →(RN≤PK)/L33 ⍝BREAK LOCK ON
  TSTEP[T;RD; 2 3]←TSTEP[T;RD; 2 3]+⌈(TSTEP[T;RD; 2 3])×(PK)
  TR1←TSTEP[T;RD;2]
  →L1 ⍝⋄ 'NO LOCK BREAK NEW TSTEP=' ⋄ 'PK=',⍕PK ⋄ TSTEP ⋄ →L1
 L12:→L1 ⋄ ⍝'ECM DOES NOT WORK' ⋄ 'ECM=',⍕ECM[T;5] ⋄ 'RN=',⍕RN ⋄ →L1
 L11:→L1 ⍝⋄'ECM DOES NOT EXIST' ⋄ →L1
 L1:→(TR1<((⍴(DS2[RD;;T+1]))-I))/L5
  TT←0 ⋄ DS2[RD;(⍳1↑((⍴(DS2[RD;;(T+1)]))-I))+I;T+1]←0 ⋄ →END
 L5:CHECK←×/(,DS2[RD;;T+1])[I+⍳TR1]
 ⍝ 'TEST = ',⍕TEST ⋄ 'CHECK FOR TRACK=',⍕CHECK
  →(CHECK≠0)/L4
  DS2[RD;(I-1)+⍳(TR1+1);T+1]←0 ⋄ →L3
 ⍝'TGT = ',(⍕T),' AGAIN FOR DETECTION'
 L33:'BREAK LOCK ON' ⋄ 'PK=',⍕PK ⋄ 'RN=',⍕RN ⋄ DS2[RD;I;(T+1)]←0 ⋄ →L3
 L3:TT←0 ⋄ STGT[RD;T]←T ⋄ ALLTGT[T]←T ⍝⋄ 'TARGET = ',(⍕TARGET)
  CAP2[RD]←CAP2[RD]+1 ⋄ →END
 L4:II←(AS2[RD;I+TR1;])⍳0 ⍝IT FINDS WHICH ELEMENT OS AS2 MATRIX IS ZERO
  AS2[RD;(I+TR1);II]←⍎(⍕RD),'2',(⍕T) ⍝GENERATE EVENTS (2=TRACK)
  TT←AS2[RD;I+TR1;]
 ⍝'THE EVENTS ROW FOR TRACK IS = ',⍕TT←AS2[RD;I+TR1;]
 END:
∇
```

```
∇ FR←ISITE FIRE F;CHECKRD;RD;FT
 ⍝
 ⍝----------------------- PURPOSE ---------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED BY THE SITE PROGRAM TO PERFORM THE
 ⍝  FIRE EVENT.
 ⍝
 ⍝----------------------- INPUT -----------------------------------+
 ⍝
 ⍝  1. THE LEFT ARGUMENT IS A VECTOR WHOSE FIRST ELEMENT IS THE
 ⍝     RADAR SITE NUMBER AND THE SECONT ONE IS THE TIME STEP.
 ⍝  2. THE RIGHT ARGUMENT IS THE NUMBER OF TARGET.
 ⍝  3. THIS FUNCTION USES SOME OTHER GLOBAL VARIABLES
 ⍝
```

```
⍝---------------------- OUTPUT ---------------------------------+
⍝
⍝ THE OUTPUT IS THE FUTURE FIRE EVENT.
⍝
⍝---------------------- MAIN PROGRAM ---------------------------+
⍝
 I←ISITE[1] ◇ RD←ISITE[2] ◇ FT←TSTEP[F;RD;3]
 →(MCAP2[RD]>0)/L3
 →L4
L3:→(FT<((ρ(DS2[RD;;F+1]))-I))/L5
 FR←0 ◇ DS2[RD;(ι((ρ(DS2[RD;;(F+1)]))-I))+I;F+1]←0 ◇ →END
L5:CHECK←×/(,DS2[RD;;F+1])[I+ιFT] ⍝◇ 'TEST FOR FIRE=',⍕CHECK
 →(CHECK≠0)/L1
 DS2[RD;(I-1)+ι(FT+1);F+1]←0
L4:FR←0 ◇ STGT[RD;F]←F ◇ ALLTGT[F]←F ◇ TSTEP[F;RD;]←TSTEP1[F;RD;]
⍝ 'TARGET ',(⍕F),' ENTER AGAIN TO DETECTION LIST'
 CAP2[RD]←CAP2[RD]+1 ◇ →END
L1:II←(AS2[RD;I+FT;])ι0 ⍝FINDS WHICH ELEMENT OF AS2 MATRIX IS ZERO
 AS2[RD;(I+FT);II]←⍎(⍕RD),'3',(⍕F) ⍝GENERATE EVENTS(3=FIRE)
 FR←AS2[RD;I+FT;]
L2: ⍝ 'THE EVENTS ROW FOR FIRE IS = ',⍕FR←AS2[RD;I+FT;]
END:
    ∇


    ∇ INT←ISITE INTER IN;CH1;CH;NNN;II;RD
 ⍝
 ⍝--------------------- PURPOSE -----------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED BY THE SITE PROGRAM TO PERFORM THE
 ⍝  INTERCEPT OF THE TARGET.
 ⍝
 ⍝--------------------- INPUT -------------------------------------+
 ⍝
 ⍝  1. THE LEFT ARGUMENT IS A VECTOR WHOSE FIRST ELEMENT IS THE
 ⍝     RADAR SITE NUMBER AND THE SECOND ONE IS THE TIME STEP.
 ⍝  2. THE RIGHT ARGUMENT IS THE NUMBER OF TARGET.
 ⍝  3. THIS FUNCTION USES SOME OTHER GLOBAL VARIABLES.
 ⍝
 ⍝--------------------- OUTPUT ------------------------------------+
 ⍝
 ⍝  1. THE TIME THAT THE INTERCEPTION TAKES TO BE DONE.
 ⍝  2. THE DISTANCE THAT THE TARGET FLY UNTIL GETS INTERCEPTED.
 ⍝  3. THE DISTANCE THAT THE INTERCEPTOR FLY UNTIL THE INTERCE
 ⍝     PTION IS DONE.
 ⍝
 ⍝--------------------- MAIN PROGRAM ------------------------------+
  I←ISITE[1] ◇ RD←ISITE[2]
  →(MCAP2[RD]>0)/L6
  →L1
 L6: ⍝ NN1←IS2[RD;; 3 6 9]
  NNN←STS[RD;I;IN] ⍝◇ 'NUMB. OF TIME STEPS=',⍕NNN
  →(NNN<((ρSEF[SS;;1])-I))/L4
  INT←0 ◇ DS2[SS;(I+(ι((ρSEF[SS;;1])-I)));IN+1]←0
  →END
 L4:CH←SEF[SS;I;IN] ⍝◇ 'CHECK FOR INTERCEPTION=',⍕CH
  CH1←×/(,SEF[SS;;IN])[I+ιNNN] ⍝◇ 'CH1=',⍕CH1
  →((CH=0),(CH1=0))/L1,L2
  →L3
 L1:INT←0 ⍝◇ 'NO TRACK ...NO INTERCPTN'
  STGT[RD;IN]←IN ◇ ALLTGT[IN]←IN ◇ TSTEP[IN;RD;]←TSTEP1[IN;RD;]
 ⍝◇ 'TGT = ',(⍕IN),' ENTER AGAIN THE DETECTION'
  CAP2[RD]←CAP2[RD]+1 ◇ →END
 L2:'LAUNCHING WAS SUCCESSFUL BUT ...NO INTERCEPTION DUE TO MASKING'
  TESTINT[SS;IN]←0 ◇ MCAP2[RD]←MCAP2[RD]-1 ◇ →L5
 L3:TESTINT[SS;IN]←1
```

```
[41] L5:II←(AS2[RD;I+NNN;])⍳0 ⍝FINDS WHICH ELEMENT OF AS2 MATRIX IS ZERO
[42]  AS2[RD;(I+NNN);II]←⍎(⍕RD),'4',(⍕IN)
[43]  INT←AS2[RD;I+NNN;]
[44] ⍝ 'THE EVENTS ROW FOR INTERCPT IS = ',⍕INT
[45] END:
    ∇
```

```
    ∇ AM←ISITE ASSES AS;CHECK;II;RD;ASES
[1]  ⍝
[2]  ⍝--------------------- PURPOSE -----------------------------------+
[3]  ⍝
[4]  ⍝  THIS FUNCTION IS CALLED BY THE SITE PROGRAM TO PERFORM
[5]  ⍝  THE TARGET DAMAGE ASSESSMENT EVENT.
[6]  ⍝
[7]  ⍝--------------------- INPUT -------------------------------------+
[8]  ⍝
[9]  ⍝  1. THE LEFT ARGUMENT IS A VECTOR WHOSE FIRST ELEMENT IS THE
[10] ⍝     RADAR SITE NUMBER AND THE SECOND ONE IS THE TIME STEP.
[11] ⍝  2. THE RIGHT ARGUMENT IS THE NUMBER OF TARGET.
[12] ⍝  3. THIS FUNCTION USES SOME OTHER GLOBAL VARIABLES.
[13] ⍝
[14] ⍝--------------------- OUTPUT ------------------------------------+
[15] ⍝
[16] ⍝  THE OUTPUT IS THE FUTURE TARGET DAMAGE ASSESSMENT.
[17] ⍝
[18] ⍝--------------------- MAIN PROGRAM ------------------------------+
[19]  I←ISITE[1] ⋄ RD←ISITE[2] ⋄ ASES←TSTEP[AS;RD;4]
[20] ⍝  IF THE RADAR DOES NOT HAVE TIME TO ASSES THE TGT (THE TGT
[21] ⍝  ENTER TO EACH OWN TERRAIN)
[22]  →(ASES<((⍴(DS2[RD;;AS+1]))-I))/L3
[23]  AM←0 ⋄ DS2[RD;(⍳((⍴(DS2[RD;;(AS+1)]))-I))+I;AS+1]←0
[24]  ASS←ASS+1 ⋄ →END
[25] ⍝ TEST IF THERE IS DETECTON DURING THE ASSES PROCCESS
[26] L3:CHECK←×/TEST←(,DS2[RD;;AS+1])[I+⍳ASES]
[27] ⍝⋄ 'TEST = ',⍕TEST ⋄ 'CHECK FOR ASSES= ',⍕CHECK
[28]  →(CHECK≠0)/L1
[29]  AM←0 ⋄ ASS←ASS+1 ⋄ STGT[RD;AS]←AS ⋄ ALLTGT[AS]←AS
[30]  ⋄ CAP2[RD]←CAP2[RD]+1 ⋄ →END
[31] ⍝ CREATE ESSES EVENTS
[32] L1:II←(AS2[RD;I+ASES;])⍳0 FINDS WHICH ELEMENT OF AS2 MATRIX IS ZERO
[33]  AS2[RD;(I+ASES);II]←⍎(⍕RD),'5',(⍕AS)
[34] ⍝GENERATE EVENTS (5=TGT ASSESS)
[35]  AM←AS2[RD;I+ASES;]
[36] ⍝'THE EVENTS ROW FOR ASSESSEMENT IS = ',⍕AM
[37] END:
    ∇
```

```
    ∇ PK←PKM PKILL R;A;B;C;X1;X2;Y1;Y2;P
[1]  ⍝
[2]  ⍝ ------------ PURPOSE ------------------------------------------
[3]  ⍝
[4]  ⍝ THIS FUNCTION IS USED TO CALCULATE:
[5]  ⍝  1.THE PROBABILITY THAT A MISSILE SITE KILLS A TARGET BY USING
[6]  ⍝    THE APPROPRIATE FUNCTION (DATA IN PKM MATRIX)
[7]  ⍝  2.THE EFFECTIVENESS OF ECM BY USING THE APPROPRIATE FUNCTION
[8]  ⍝    (DATA IN ECM MATRIX)
[9]  ⍝
[10] ⍝------------ INPUTS -------------------------------------------
[11] ⍝  1. THE FIRST ARGUMENT IS THE PK MATRIX OR THE ECM MATRIX
[12] ⍝  2. THE SECOND ARGUMENT IS A TWO ELEMENTS VECTOR (SITE AND
[13] ⍝     DISTANCE
[14] ⍝
```

```
⍝------------ OUTPUT -----------------------------------------
⍝
⍝  1.THE PROBABILITY THAT A MISSILE SITE KILLS A TARGET
⍝  2.THE EFFECTIVENESS OF ECM
⍝
⍝------------ MAIN PROGRAM -----------------------------------
 A←PKM[R[1];1]
 B←PKM[R[1];2]
 C←PKM[R[1];3]
 P←PKM[R[1];4]
 →(R[2]>A)/L1
 X1←Y1←0 ⋄ X2←A ⋄ Y2←P ⋄ →L3
L1:→(R[2]>B)/L2
 X1←A ⋄ Y1←P ⋄ X2←B ⋄ Y2←P ⋄ →L3
L2:→(R[2]>C)/L4
 X1←B ⋄ Y1←P ⋄ X2←C ⋄ Y2←0
⍝----------- THE USED FUNCTION ---------------
L3:PK←(((R[2]-X1)×(Y2-Y1))÷(X2-X1))+Y1 ⋄ →L5
L4:PK←0
L5:
∇
```

```
∇ RN←RANDOM
 ⍝
 ⍝-------------------- PURPOSE ---------------------------------+
 ⍝
 ⍝  THIS FUNCTION IS USED BY OTHER PROGRAMS TO GENERATE A RUNDOM
 ⍝  NUMBER
 ⍝
 ⍝-------------------- INPUT -----------------------------------+
 ⍝
 ⍝  NONE
⍝
⍝-------------------- OUTPUT ----------------------------------+
⍝
⍝  THE OUTPUT IS A RUNDOM NUMBER.
⍝
⍝-------------------- MAIN PROGRAM ----------------------------+
 RN←(?100)÷100
∇
```

APPENDIX G

This Appendix contains all data of the pre-calculating phase of the air model. It also lists the data of the attrition rate of the three aircraft formations by running the dynamic phase of the air model.

ATTRITION RATE OF THE THREE AIRCRAFT FORMATIONS

1. NORMAL CASE

TARGET1

0 1 0 0 0 2 0 2 0 2 0 0 0 0 0 1 0 0 1 0 3 0 0 0 1 0 1 1 2 1 0 3 0 0 1 0 0 2 1
1 1 0 1 0 1 0 2 1 0 0

TARGET2

1 0 0 1 1 1 0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 0 1 0 0 1 0 1 0 0 1 0 0 0 0 1 0 1 0
1 1 1 0 1 0 1 0 1 1 0

TARGET3

1 2 3 2 2 3 2 1 3 4 1 3 4 2 2 2 2 3 3 2 2 2 1 2 4 1 0 0 5 3 2 1 2 1 1 1 1 1 3
3 2 3 3 3 4 1 2 2 3 4

2. CASE WITH DIFFERENT IFF PROBABILITIES

TARGET1

2 0 0 1 1 0 1 0 1 2 1 1 2 2 1 4 3 3 2 3 0 0 1 1 0 0 0 1 2 2 0 2 1 1 1 1 1 0 0
0 2 1 1 1 2 1 1 0 1 0

TARGET2

1 1 0 1 1 0 2 2 3 2 3 2 0 2 3 0 2 3 2 4 1 0 0 0 3 1 1 1 0 0 0 0 2 0 0 1 1 0
4 0 0 1 1 0 1 0 1 0 1

TARGET3

2 0 0 0 0 0 1 1 1 3 0 2 1 3 1 3 2 4 4 4 1 1 4 3 1 2 1 3 4 4 4 3 4 3 2 4 0 6 6
3 3 2 4 5 1 2 3 1 2 4

ATTRITION RATE OF THE THREE AIRCRAFT FORMATIONS

1. NORMAL CASE

TARGET1

0 1 0 0 0 2 0 2 0 2 0 0 0 0 0 1 0 0 1 0 3 0 0 0 1 0 1 1 2 1 0 3 0 0 1 0 0 2 1
1 1 0 1 0 1 0 2 1 0 0

TARGET2

1 0 0 1 1 1 0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 0 1 0 0 1 0 1 0 0 1 0 0 0 0 1 0 1 0
1 1 1 0 1 0 1 0 1 1 0

TARGET3

1 2 3 2 2 3 2 1 3 4 1 3 4 2 2 2 2 3 3 2 2 2 1 2 4 1 0 0 5 3 2 1 2 1 1 1 1 1 3
3 2 3 3 3 4 1 2 2 3 4

2. CASE WITH DIFFERENT IFF PROBABILITIES

TARGET1

2 0 0 1 1 0 1 0 1 2 1 1 2 2 1 4 3 3 2 3 0 0 1 1 0 0 0 1 2 2 0 2 1 1 1 1 1 0 0
0 2 1 1 1 2 1 1 0 1 0

TARGET2

1 1 0 1 1 0 2 2 3 2 3 2 0 2 3 0 2 3 2 4 1 0 0 0 3 1 1 1 0 0 0 0 0 2 0 0 1 1 0
4 0 0 1 1 0 1 0 1 0 1

TARGET3

2 0 0 0 0 0 1 1 1 3 0 2 1 3 1 3 2 4 4 4 1 1 4 3 1 2 1 3 4 4 4 3 4 3 2 4 0 6 6
3 3 2 4 5 1 2 3 1 2 4

3. CASE WHEN COMMAND AND CONTROL MODEL IS NOT APPLIED

TARGET1

1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 1 2 0 1 0 1 1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 1
2 0 1 1 0 1 0 0 0 1 0

TARGET2

1 2 0 2 1 2 1 1 0 1 3 0 3 1 4 1 0 1 2 2 1 2 1 2 0 2 1 2 1 1 0 1 3 0 3 1 4 1 0
1 2 2 2 2 1 2 0 2 1 2

TARGET3

2 5 1 2 1 2 5 4 2 3 3 4 0 1 1 5 1 2 5 5 1 2 2 5 1 2 1 2 5 4 2 3 3 4 0 1 1 5 1
2 5 5 0 4 2 5 1 2 1 2

4. CASE WHEN RADAR OPERATION IS DEGRADED

TARGET1

1 1 0 0 0 1 0 1 1 1 0 0 1 2 0 0 0 1 1 0 2 1 0 1 0

TARGET2

0 1 0 2 2 0 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 1 1 2 1

TARGET3

0 0 0 1 1 3 2 3 1 2 2 1 0 1 1 1 3 2 3 0 0 2 2 1 2

5. CASE WHEN ECM MODEL IS NOT APPLIED

TARGET1

0 1 1 1 0 0 0 1 1 0 1 2 1 0 0 0 1 1 1 1 1 1 1 0 0 2 1 1 1 2

TARGET2

1 3 0 1 1 0 1 2 1 0 1 1 0 0 2 1 1 1 1 1 0 3 2 0 2 0 1 0 1 0

TARGET3

5 5 3 3 5 7 1 5 5 4 4 4 4 5 1 6 1 3 4'1 3 3 3 6 5 5 7 5 5 4

ATRITION RATE OF THE THREE AIRCRAFT FORMATIONS

1. FLIGHT LEVEL = 500 FEET

TARGET1

1 0 1 2 0 0 1 1 1 1 1 1 0 3 1 1 2 0 1 1 1 2 0 2 1 0 0 0 1 0 1 1 1 1 1 0 1 1 0
2 1 1 0 0 2 0 0 2 0 1 1 1 2 0 2 1 0 0 0

TARGET2

0 0 0 2 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 1 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0

TARGET3

1 2 1 1 1 1 1 1 1 1 0 1 0 1 0 1 0 0 0 2 2 1 2 0 0 0 1 1 1 1 1 0 1 0 1 0 0 1 2
0 0 1 0 1 1 0 1 0 0 0 2 2 1 2 0 0 0 1 1

2. FLIGHT LEVEL = 1000 FEET

TARGET1

0 1 0 0 0 2 0 2 0 2 0 0 0 0 0 1 0 0 1 0 3 0 0 0 1 0 1 1 2 1 0 3 0 0 1 0 0 2 1
1 1 0 1 0 1 0 2 1 0 0

TARGET2

1 0 0 1 1 1 0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 0 1 0 0 1 0 1 0 0 1 0 0 0 0 1 0 1 0
1 1 1 0 1 0 1 0 1 1 0

TARGET3

1 2 3 2 2 3 2 1 3 4 1 3 4 2 2 2 2 3 3 2 2 2 1 2 4 1 0 0 5 3 2 1 2 1 1 1 1 1 3
3 2 3 3 3 4 1 2 2 3 4

3. FLIGHT LEVEL = 2000 FEET

TARGET1

1 1 1 0 1 1 0 0 0 0 0 1 1 0 1 1 1 1 0 0 1 1 0 1 0 1 1 0 1 2 0 4 1 0 0 1 1 1 1
1 1 0 2 0 0 0 1 0 1 1

TARGET2

0 1 1 1 1 1 0 0 0 0 0 1 0 0 1 0 1 1 0 0 3 0 1 0 0 0 0 0 0 0 0 0 1 0 1 1 0 1 1
0 2 1 0 1 0 0 0 0 1 0

TARGET3

1 1 2 2 2 2 1 2 2 2 2 2 1 2 2 1 4 4 5 1 1 0 3 2 4 3 1 3 0 3 3 2 2 1 2 1 2 2 3
5 4 2 2 0 2 2 1 1 2 2

4. FLIGHT LEVEL = 5000 FEET

TARGET1

0 0 0 3 0 1 2 1 0 1 0 0 1 0 1 0 0 1 3 0 1 1 2 1 2 1 0 1 1 1 2 2 1 0 1 0 1 1 0
1 1 1 1 1 0 0 3 2 1 3

TARGET2

0 0 1 0 0 1 0 1 0 0 0 1 0 0 1 1 0 1 1 1 0 1 0 0 2 2 0 1 0 0 0 0 2 0 1 0 1 0 2
0 1 1 0 0 0 3 1 1 0 2

TARGET3

1 2 1 0 1 5 2 4 1 1 2 2 2 1 2 2 2 2 0 0 2 1 0 4 2 2 3 2 1 1 2 1 2 4 3 1 1 2 2.
2 1 3 4 1 4 0 2 2 1 4

5. FLIGHT LEVEL = 10000 FEET

TARGET1

1 0 0 3 0 2 0 0 0 0 1 0 1 0 1 0 0 1 1 1 2 1 1 0 0 0 0 1 2 2 1 1 0 1 1 2 2 1 0
1 1 0 2 1 0 0 0 0 0 0 0 2

TARGET2

2 0 1 0 1 1 0 0 1 0 0 0 0 0 1 0 1 0 0 0 1 0 0 0 1 1 1 1 1 0 0 1 2 1 1 0 0 1 0
0 1 0 0 1 1 1 0 1 0 0 0 1

TARGET3

0 4 2 1 2 1 1 3 2 0 3 2 2 0 3 1 5 2 2 1 1 1 2 1 1 3 1 2 2 2 3 1 3 1 0 1 1 2 0
3 1 3 1 0 1 1 2 4 3 3 1 1

ORIGINAL DATA OF THE SPECIFIC SENARIO

GRID SQUARE ALTITUDES

0 0 0 0 0 0 0 0 0 0 0 0 200
500 600 800 50 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1500 1550
1500 500 200 0 0 200 500 700
0 0 0 0 0 0 0 0 0 0 500 2000 2000
1700 200 10 10 230 1000 510 750
0 0 0 0 0 0 0 0 0 0 1000 1400 650
200 250 200 470 590 1100 520 600

```
    0      0      0      0    500   1500    250      0      0      0   2000   1500    500
         210    260   2300    500    510    900   1000    700
    0      0      0   3000   2000   1000    500    650     60    500   1000   1000    750
         520   2000   1500   1100    520   1000    350    310
    0      0   2500   4000   1500   2000    500    550    850    550   1100    250   2500
        3000   3100   2000   2980    510    250    100     40
    0   3500   2500   2500   2000   1000    200   1000    750   1000    250   2500   2000
        2100   3000   1100   1000    410    190     50     45
  350   2000   2100   1500    500    250   1500   3000    500    250    750   2200   2400
        2500   2600   2500    500    300     60    100     50
 2000   2750   1000    200    150   2000   2800   1000    750   2500   1800   2000    700
        1500   1000    750    100     60    190    120    150
 1500   1000    200    250    750   1750   2500   2600   2000   2000   1300    250    130
         290    150     20     60     80    200    130    200
 1600    210    900   1100   1700   2000   3500   3000   3100    800    650    150    120
         260     90    100    150    100    210    210    350
  300   1000   1500   2000   3000   2500   2000   1500   1500   1100    250    130    100
         100     80    100    190    180    230    210   1000
 1500   1600   2500   4000   3000   2000   1250   1500    500    250    150    140    110
         100     90    150    210    250    250    500   2100
 2500   2500   1750   3000   2750   2000   1000    250    200    150    150    140    110
         130    200    300    300    260    500   1050   1800
 3000   2700   2000   3100   1500    600    500    400    200    120    140    145    140
         180    250    350    500    410  ·1000   1500   1900
 2000   1100    650   3000    800    480    225    200    150    130    130    180    150
         210    480    500    300    580   2100   2000   1990
 1900    800    600    500    280    270    180    150    120    120    120    280    200
         400    510   1300   1000   1000   2600   2500   2000
  600    550    400    300    250    190    180    160    200    225    250    300    310
         700   1500   1600   2100   2900   3800   5000   4500
 1360    300    270    260    200    120    250    280    300    340    280    390    700
        1100   1000   2500   3000   3100   3200   3800   4900
  200    230    210    220    190    210    240    260    310    350    300    500   1480
        1150   1500   3400   3500   3200   5000   4900   4100
  190    180    170    180    150    220    250    265    320    360    540   1500   1500
        2100   3000   5000   4000   3700   6500   6900   7000
  180    170    200    240    160    230    270    280    330    500    800   2000   1600
        3000   3200   5200   7100   7000   8900   9050   8100
  220    240    250    260    260    260    280    500    700   2000   2800   2100   1800
        3100   7000   8100   9000  10100   9100   9200   9700
  270    270    260    270    275    280    700    750   1500   1000   3400   3100   4200
        4500   5500   8500   9500  11200  10000  11000   9900
  290    295    295    320    530   1400   1560   2000   2500   2500   3800   6000   6500
        8100   6500   7000   7500  10000  11000  13000  12000
  400    490    750   1500   1000   1700   2900   3000   3100   5000   6500   8000   8500
        9000   8500  10000   8000   7100   7500   7000   6000
  750    900   2000   1800   2000   3500   3600   5100   7000   7000   9000   9900   9500
```

OUTPUT OF TERRAIN MODEL

TERRAIN GRID SQUARE AVERAGE ALTITUDES

```
    0      0      0      0      0      0      0      0      0      0    375    813    938
         775    525    263     13     50    175    300
    0      0      0      0      0      0      0      0      0    125   1000   1763   1688
         975    228     55     60    358    553    615
    0      0      0      0      0      0      0      0      0    375   1225   1513   1138
         588    165    173    325    730    783    595
    0      0      0    125    500    438     63      0      0    750   1475   1013    390
         230    753    868    518    775    880    705
    0      0    750   1375   1250    813    350    178    140    875   1375    938    495
         748   1515   1350    658    733    813    590
    0    625   2375   2625   1625   1000    550    528    490    788    838   1125   1693
        2155   2150   1895   1278    570    425    200
  875   2125   2875   2500   1625    925    563    788    788    725   1025   1813   2400
        2800   2300   1770   1225    340    148     59
 1463   2525   2150   1625    938    738   1425   1313    625    563   1425   2275   2250
```

```
       2550  2300  1275   553   240   100    62
 1775  1963  1200   588   725  1638  2075  1313  1000  1325  1688  1825  1775
       1900  1713   963   240   153   118   105
 1813  1238   413   338  1163  2263  2225  1588  1813  1900  1338   770   655
        735   480   233    75   133   160   150
 1078   578   613   950  1550  2438  2900  2675  1975  1188   588   163   200
        198    90    83    98   148   188   223
  778   903  1375  1950  2300  2500  2500  2275  1625   700   295   125   145
        133    93   135   155   180   215   443
 1100  1650  2500  3000  2625  1938  1563  1250   838   438   168   120   103
         93   105   163   208   228   298   953
 2025  2088  2813  3188  2438  1563  1000   613   275   175   145   125   113
        130   185   240   255   315   575  1363
 2675  2238  2463  2588  1713  1025   538   263   168   140   144   134   140
        190   275   363   368   543  1013  1563
 2200  1613  2188  2100   845   452 , 332   238   150   130   149   154   170
        280   395   413   448  1023  1650  1848
 1450   788  1188  1145   458   289   189   155   130   125   178   203   240
        400   698   775   720  1570  2300  2123
  963   588   450   333   248   205   168   158   167   179   238   273   403
        778  1228  1500  1750  2575  3475  3500
  703   380   308   253   190   185   218   235   267   274   305   425   703
       1075  1650  2300  2775  3250  3950  4550
  523   253   240   218   180   205   258   288   325   318   368   768  1108
       1188  2100  3100  3200  3625  4225  4425
  200   198   195   185   193   230   254   289   335   388   710  1245  1558
       1938  3225  3975  3600  4600  5825  5725
  180   180   198   183   190   243   267   299   378   550  1210  1650  2050
       2825  4100  5325  5450  6525  7838  7763
  203   215   238   230   228   260   333   453   883  1525  1925  1875  2375
       4075  5875  7350  8300  8775  9063  9013
  250   255   260   267   269   380   558   863  1300  2300  2850  2800  3400
       5025  7275  8775  9950 10100  9825  9950
  282   280   287   349   622   985  1253  1688  1875  2675  4075  4950  5825
       6150  6875  8125  9550 10550 11250 11475
  369   458   717   838  1158  1890  2365  2650  3275  4450  6075  7250  8025
       8025  8000  8125  8150  8900  9625  9500
  635  1035  1513  1575  2050  2925  3650  4550  5525  6875  8350  8975  9275
       9650 10375  9275  7300  7225  7225  6775
```

DATA OF RADAR SITE MINIMUM ALTITUDE MODEL
----

1. SITE 1

```
  ¯1   ¯1    0    1    1    0   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1    1    0    0    1    0    1    1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1 1957    1    1    1   66    0  229   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
2161 1841 1587  126  501  439  510  292   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
2145 1824 1567 1375  ¯10  814  529  302   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
3495 2890 3283 2625 1626 1001  954  529   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1 4704 3977 3488 1977 2083  943  964   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1   ¯1 4846 3088 2392 2480 2691   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
  ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
       ¯1   ¯1   ¯1   ¯1   ¯1
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¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
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      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
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      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
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2. SITE 2

```
¯1   ¯1   ¯1   ¯1   ¯1   ¯1 2512 2313 2188 2138 2794 3574 3831   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1 2400 2125 1922 1793 1741 2290 2974 3251 3630   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1 2080  493 1806 1597 1463 1408 2263 2445 2748 1998 3745
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1 1873 1566  367 1339 1197 1138 1782 1995 1485 2843 3377
    3988   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1 2102 1731 1423 1179  368  999  931 1375 1098 2073 2556 3116
    3745   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1 2625 1654 1346 1100  919  491  788  839 1443 1884 3247 4040
    4898   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1 2501 1643 1335 1089  907  788  ¯10 1025 1813 2481 3214 4011
    4873   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1 2584 2133 1990 1617 1313  625  564 1425 2276 2952 3731 4153
    4999   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1 3094 2596 2492 2075 1313 1000 1325 1899 2177 3398 4109 4922
    5820   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1 3266 2793 2226 1588 1813 1900 2165 2688 3061 4651 5410
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1 2956 2900 2675 2244 2389 2711 3286 3621 4072 6032
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1 3488 3208 2740 2941 2632 3962 4267 4687   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1 3488 3208 2740 2941 2632 3962 4267 4687   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1 3624 3557 3591 4146   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
      ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
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        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1   ¯1
        ¯1   ¯1   ¯1   ¯1   ¯1
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3. SITE 3

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¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     892    879    905    ¯1     ¯1
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     ¯1     ¯1     801    714    666    654    678    1798   1977
       ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     743    594    620    543    503    493    522    1460   1640
       1887   ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     ¯1     605    470    383    431    402    395    416    1185   1369
       4098   4777   ¯1     ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     649    510    391    323    298    361    360    858    976    3001
       3629   4347   5144   ¯1     ¯1     ¯1     ¯1
¯1     ¯1     ¯1     557    388    324    282    303    335    389    710    2035   2620
```

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         3296   4047   4870     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1    526    377    291    267    299    379    ¯10   1210   1774   2414
         3121   4100   5325     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1    660    488    593    492   1257    883   1525   1925   3026   2560
         4075   5875   7351     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1   1028   2939   2370   1875   1467   3790   3390   4149   3519   4594
         5791   7275   8775     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1   3804   3184   2640   2181   6539   5602   5343   5850   6963   5825
         7031   7581   9137     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1     ¯1   3538   3022   9450   8290   7557   7364   7746   8635   9911
         8026   9146     ¯1     ¯1     ¯1     ¯1     ¯1
    ¯1     ¯1     ¯1     ¯1   3989  12498  11198  10209   9606   9450   9760  10499  11600
        12989     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
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4. SITE 4

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 20787  20455  20246  20162  20204  20372  20663  21076  21609  22257     ¯1     ¯1     ¯1
           ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
 19123  18779  18562  18475  18518  18692  18994  19423  19973  20642  21425  22317     ¯1
           ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
 17527  17168  16942  16851  16896  17077  17393  17838  18409  19102  19910  20829  21853
           ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
 15998  15623  15386  15290  15338  15528  15858  16324  16919  17638  18475  19423   8119
         8684     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
 14540  14144  13894  13793  13844  14045  14392  14881  15504  16254  17123  18103   7505
         6594   7142     ¯1     ¯1     ¯1     ¯1     ¯1
 13153  12734  12467  12360  12413  12627  12997  13514  14169  14954  15858   6452   5630
         6114   6656   7257     ¯1     ¯1     ¯1     ¯1
 11841  11392  11106  10990  11048  11278  11674  12224  12918  13743   5527   4792   5212
         5690   5855   6428   7061     ¯1     ¯1     ¯1
 10607  10122   9810   9683   9747   9998  10427  11019  11757   4727   4081   4437   4851
         4990   5498   6065   6693     ¯1     ¯1     ¯1
  9458   8927   8581   8440   8511   8790   9262   9904   4054   3496   3788   4137   4250
         4692   5193   5755   6378   7061     ¯1     ¯1
  8404   7814   7422   7260   7342   7659   8187   8893   3038   3266   3318   3635   4011
         4446   4941   5498   6116   2726     ¯1     ¯1
  7462   6794   6338   6144   6242   6616   7219   2706   2869   2894   3144   3453   3821
         4250   1553   1199   1496   1853     ¯1     ¯1
  3650   5891   5338   5092   5217   5679   2501   2598   2594   2776   3017   3318    631
          737    431    616    672    965     ¯1     ¯1
  3442   3167   4454   4105   4287   2352   2359   2415   2528    695    608    242    103
          142    242    418    643    931   1282     ¯1
  2464   3035   2814   3188   2439   2370   1148    784    275    176    145    126    114
          146    241    399    620    905   1252     ¯1
  2675   2431   2463    ¯10   1714   1026    539    264    169    140    145    134    140
          190    289    452    677    965   1317     ¯1
  2478   2435   2189   2101    846    478    333    239    150    131    149    154    170
          280    395    570    807   1107   1650     ¯1
  2524   2013   2069   1813   1778    289    189    155    130    126    179    203    241
          400    699    905   1173   1570     ¯1     ¯1
  1963   1969   1552   1588   1569   1505    169    158    167    180    239    273    403
          779   1228   1501   1820   2575     ¯1     ¯1
  1989   1967   1407   1426   1416   1382   1339    236    267    275    305    426    703
         1075   1650   2301   2775   3250     ¯1     ¯1
  2059   2016   1319   1327   1323   1309   1295   1292    325    319    368    768   1108
         1291   2100   3100   3540   3677     ¯1     ¯1
  2181   1294   1291   1291   1291   1292   1300   1323    336    389    711   1245   1559
         1938   3225   3975   4470     ¯1     ¯1     ¯1
  2358   1340   1324   1318   1321   1333   1358   1402   1470    551   1210   1650   2050
         2825   4100   5325   5896     ¯1     ¯1     ¯1
  2593   1445   1419   1409   1414   1434   1473   1533   1621   1740   1926   1875   2375
         4075   5876   7350     ¯1     ¯1     ¯1     ¯1
  1668   1610   1576   1562   1569   1596   1646   1720   1824   2301   2850   2801   3400
         5025   7275     ¯1     ¯1     ¯1     ¯1     ¯1
  1904   1836   1795   1779   1787   1820   1878   1965   2082   2675   4075   4950   5826
         6150   6876     ¯1     ¯1     ¯1     ¯1     ¯1
  2200   2124   2078   2059   2069   2106   2365   2650   3275   4450   6075   7250   8025
           ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
  2557   2474   2423   2403   2413   2925   3650   4550   5525   6875   9350   8975     ¯1
           ¯1     ¯1     ¯1     ¯1     ¯1     ¯1     ¯1
```

DATA OF MOVEMENT MODEL

1. TARGET1

TIME STEPS

1	2	3	4	5	6	7	8	9	10	11	12	13
	14	15	16	17	18	19	20	21	22	23	24	25
	26	27	28	29	30	31	32	33	34	35	36	37
	38	39	40	41	42	43	44	45	46	47	48	49
	50	51	52	53	54	55	56	57	58	59	60	61
	62	63	64	65	66	67	68	69	70	71	72	73
	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97
	98	99	100	101	102	103	104	105	106	107	108	109
	110	111	112	113	114	115	116	117	118	119	120	121
	122	123	124	125	126	127	128	129	130	131	132	133
	134	135	136	137	138	139	140	141	142	143	144	145
	146	147	148	149	150	151	152	153	154	155	156	157
	158	159	160	161	162	163	164	165	166	167	168	169
	170	171	172	173	174	175	176	177	178	179	180	181
	182	183	184	185	186	187	188	189	190	191	192	193
	194	195	196	197	198	199	200	201	202	203	204	205
	206	207	208	209	210	211	212	213	214	215	216	217
	218	219	220	221	222	223	224	225	226	227	228	229
	230	231	232	233	234	235	236	237	238	239	240	241
	242	243	244	245	246	247	248	249	250	251	252	253
	254	255	256	257	258	259	260	261	262	263	264	265
	266											

X CORDINATE

2	3	4	5	6	7	9	10	11	12	13	14	16
	17	18	19	20	21	23	24	25	26	27	28	29
	31	32	33	34	35	36	37	38	39	40	41	42
	43	44	45	46	47	48	49	50	51	52	53	54
	55	56	57	58	59	60	62	63	64	65	66	67
	68	69	70	71	72	73	73	74	74	74	75	75
	76	76	77	77	78	78	79	79	79	80	80	81
	81	82	82	83	83	83	84	84	84	85	85	86
	86	86	87	87	87	88	88	88	89	89	89	90
	90	90	91	91	91	92	92	92	93	93	93	94
	94	94	95	0	0	0	0	0	0	93	92	92
	91	91	90	89	89	88	88	87	86	86	85	85
	84	84	83	82	82	81	81	80	79	79	78	78
	77	77	77	77	77	78	78	78	78	78	78	78
	78	78	78	78	78	79	79	79	79	79	79	79
	79	79	79	78	78	78	77	77	77	76	76	76
	75	75	74	74	74	73	73	73	72	72	72	71
	71	71	69	68	67	66	65	64	62	61	60	59
	58	57	55	54	53	52	51	50	48	47	46	45
	44	43	41	40	39	38	37	36	34	33	32	31
	30	29	27	26	25	24	23	22	20	19	18	17
	16	15	13	12	11	10	9	8	6	5	4	3
	2											

Y CORDINATE

110	110	109	109	109	109	109	109	109	108	108	108	108
	108	108	108	107	107	107	106	105	105	104	104	103
	103	102	101	101	100	100	99	98	98	97	97	96
	96	95	94	94	93	93	92	91	91	90	90	89
	89	88	87	87	86	86	85	84	82	81	80	79
	78	77	76	75	74	73	72	71	70	68	67	66
	65	64	63	62	61	60	58	57	56	55	53	52

51	49	48	47	45	44	43	42	40	39	38	36
35	34	33	31	30	29	27	26	25	24	22	21
20	18	17	0	0	0	0	0	0	15	16	17
18	19	21	22	23	24	25	27	28	29	30	31
33	34	35	36	37	39	40	41	42	43	45	46
47	48	49	51	52	53	54	55	56	58	59	60
61	62	63	65	66	67	68	69	70	71	73	74
75	76	77	78	79	81	82	83	84	85	86	87
88	89	91	92	93	94	95	96	97	98	99	101
102	103	103	103	103	103	103	103	103	103	103	103
103	103	103	103	103	103	103	103	103	103	103	103
103	103	103	103	103	103	103	103	103	103	103	103
103	103	103	103	103	103	103	103	103	103	103	103
103	103	103	103	103	103	103	103	103	103	103	103
103											

ALTITUDES

1175	1175	1175	1175	1175	1553	1553	1553	1553	1553	1783	1783	1783
	1783	1783	1880	1880	1880	1880	1880	1813	1733	1733	1733	1733
	1570	1570	1570	1570	1570	1570	1340	1340	1340	1340	1340	1340
	1240	1553	1553	1553	1553	1553	1240	1240	1240	1240	1240	1963
	1233	1233	1233	1233	1233	1233	1083	1083	1083	1090	1090	1093
	1093	1093	1093	1093	1093	1105	1105	1093	1093	1093	1093	1093
	1103	1103	1103	1103	1103	1103	1125	1125	1125	1125	1125	1145
	1145	1145	1145	1145	1145	1175	1175	1175	1175	1140	1168	1168
	1168	1168	1263	1263	1263	1263	1263	1538	1538	1538	1538	2025
	2025	2025	1452	1452	1845	1845	1845	1845	1845	3100	3100	3100
	3100	3188	3188	0	0	0	0	0	0	4188	4188	4188
	4188	4100	4588	4588	4588	4588	3713	3713	3713	3713	3713	3025
	3563	3563	3563	3563	3000	3000	3000	3000	3000	2613	3250	3250
	3250	2250	1838	1838	1838	1838	1838	1438	1438	1438	1438	1438
	1168	1168	1168	1168	1168	1125	1125	1125	1125	1125	1113	1113
	1113	1113	1113	1103	1093	1093	1093	1093	1093	1105	1105	1105
	1105	1105	1163	1163	1163	1163	1163	1163	1155	1155	1155	1155
	1155	1180	10180	10180	10180	10148	10148	10148	10148	10148	10133	10133
	10133	10133	10133	10153	10153	10153	10153	10153	10240	10240	10240	10240
	10240	10240	10340	10340	10340	10340	10340	10570	10570	10570	10570	10570
	10733	10733	10733	10733	10733	10775	10775	10775	10775	10775	10730	10730
	10730	10730	10730	10358	10358	10358	10358	10358	10050	10050	10050	10050
	10050											

COURSE

97	97	97	97	97	97	97	97	97	97	97	97	97
	97	97	97	97	97	97	97	97	97	97	97	97
	97	97	97	97	97	120	120	120	120	120	120	120
	120	120	120	120	120	120	120	120	120	120	120	120
	120	120	120	120	120	120	120	120	120	120	120	120
	120	120	120	120	120	120	157	157	157	157	157	157
	157	157	157	157	157	157	157	157	157	157	157	157
	157	157	157	157	157	165	165	165	165	165	165	165
	165	165	165	165	165	165	165	165	165	165	165	165
	165	165	165	165	165	165	165	165	165	165	165	165
	165	165	165	0	0	0	0	0	0	334	334	334
	334	334	334	334	334	334	334	334	334	334	334	334
	334	334	334	334	334	334	334	334	334	334	334	334
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	4	4	342	342	342	342	342	342	342	342	342	342
	342	342	342	342	342	342	342	342	342	342	342	342
	342	342	270	270	270	270	270	270	270	270	270	270
	270	270	270	270	270	270	270	270	270	270	270	270
	270	270	270	270	270	270	270	270	270	270	270	270
	270	270	270	270	270	270	270	270	270	270	270	270
	270	270	270	270	270	270	270	270	270	270	270	270
	270											

SPEED

420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	480	480	480	480	480	480	480
	480	480	480	480	480	480	480	480	480	480	480	480
	480	480	480	480	480	480	480	480	480	480	480	480
	480	480	480	0	0	0	0	0	0	480	480	480
	480	480	480	480	480	480	480	480	480	480	480	480
	480	480	480	480	480	480	480	480	480	480	480	480
	480	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420											

2. TARGET 2

TIME STEPS

1	2	3	4	5	6	7	8	9	10	11	12	13
	14	15	16	17	18	19	20	21	22	23	24	25
	26	27	28	29	30	31	32	33	34	35	36	37
	38	39	40	41	42	43	44	45	46	47	48	49
	50	51	52	53	54	55	56	57	58	59	60	61
	62	63	64	65	66	67	68	69	70	71	72	73
	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97
	98	99	100	101	102	103	104	105	106	107	108	109
	110	111	112	113	114	115	116	117	118	119	120	121
	122	123	124	125	126	127	128	129	130	131	132	133
	134	135	136	137	138	139	140	141	142	143	144	145
	146	147	148	149	150	151	152	153	154	155	156	157
	158	159	160	161	162	163	164	165	166	167	168	169
	170	171	172	173	174	175	176	177	178	179	180	181
	182	183	184	185	186	187	188	189	190			

X CORDINATE

0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	2
	3	4	5	6	7	8	9	10	12	13	14	15
	16	17	18	19	20	21	23	24	25	26	27	28
	29	30	31	32	34	35	36	37	38	39	40	42
	43	44	45	46	47	49	50	51	52	53	54	56
	57	58	59	60	61	63	64	65	66	67	68	70
	71	72	73	74	75	76	77	78	79	80	81	82
	83	84	85	86	87	88	89	90	91	92	93	94
	96	97	98	99	100	101	102	103	104	105	106	107
	108	109	110	111	112	113	113	114	115	116	117	118
	119	120	121	121	122	123	124	125	126	127	128	128
	129	130	131	132	133	134	135	135	136	137	138	139
	140	141	142	143	143	144	145	146	147	148	149	150
	150	151	152	153	154	155	156	157	157			

Y CORDINATE

0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	81
	81	80	80	80	79	79	78	78	78	77	77	77
	76	76	75	75	75	74	74	74	73	73	72	72
	72	71	71	70	70	70	70	69	69	69	69	69
	69	69	69	69	68	68	68	68	68	68	68	68
	67	67	67	67	67	67	67	67	66	66	66	66
	66	66	65	65	64	64	63	63	62	61	61	60
	60	59	59	58	58	57	57	56	55	55	54	54
	53	53	52	52	51	50	50	49	49	48	48	47
	47	46	46	45	44	43	42	42	41	40	39	39
	38	37	36	36	35	34	33	33	32	31	30	29
	29	28	27	26	26	25	24	23	23	22	21	20
	20	19	18	17	16	16	15	14	13	13	12	11
	10	10	9	8	7	7	6	5	4			

ALTITUDES

0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	20775
	20775	20775	20775	20775	20975	20975	21688	21688	21688	21138	21138	21138
	21138	21138	21138	20390	20390	20390	20390	20390	20495	20495	20938	20938
	20938	20938	21125	21125	21125	21125	21125	21813	21813	21813	21813	21813
	22275	22275	22275	22275	22275	21825	21825	21825	21825	21825	21825	20770
	20770	20770	20770	20770	20163	20163	20163	20163	20588	20295	20295	20295
	20295	20295	20168	20168	20168	20168	20168	20168	20145	20145	20145	20175
	20175	20175	20140	20140	20140	20140	20140	20140	20130	20130	20150	20150
	20150	20130	20130	20130	20130	20130	20130	20167	20167	20158	20158	20158
	20158	20235	20235	10235	10235	10235	10218	10218	10258	10258	10258	10258
	10258	10258	10230	10230	10230	10230	10230	10230	10230	10243	10190	10190
	10190	10190	10190	10190	10228	10228	10230	10230	10230	10230	10230	10267
	10267	10267	10260	10260	10260	10260	10287	10287	10287	10287	10280	10280
	10280	10458	10458	10458	10458	10458	10369	10635	10635			

COURSE

0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	109
	109	109	109	109	109	109	109	109	109	109	109	109
	109	109	109	109	109	109	109	109	109	109	109	109
	109	109	109	109	109	109	96	96	96	96	96	96
	96	96	96	96	96	96	96	96	96	96	96	96
	96	96	96	96	96	96	96	96	96	96	96	96
	96	96	118	118	118	118	118	118	118	118	118	118
	118	118	118	118	118	118	118	118	118	118	118	118
	118	118	118	118	118	118	118	118	118	118	118	118
	118	118	118	131	131	131	131	131	131	131	131	131
	131	131	131	131	131	131	131	131	131	131	131	131
	131	131	131	131	131	131	131	131	131	131	131	131
	131	131	131	131	131	131	131	131	131	131	131	131
	131	131	131	131	131	131	131	131	131			

SPEED

0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420

3. TARGET3

TIME STEPS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	30	31	32	33	34	35	36	37	38	39	40	41	42	43
	44	45	46	47	48	49	50	51	52	53	54	55	56	57
	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97	98	99
	100	101	102	103	104	105	106	107	108	109	110	111	112	113
	114	115	116	117	118	119	120	121	122	123	124	125	126	127
	128	129	130	131	132	133	134	135	136	137	138	139	140	141
	142	143	144	145	146	147	148	149	150	151	152	153	154	155
	156	157	158	159	160	161	162	163	164	165	166	167	168	169
	170	171	172	173	174	175	176	177	178	179	180	181	182	183
	184	185	186	187	188	189	190	191	192	193	194	195	196	197
	198	199	200	201	202	203	204	205	206	207	208	209	210	211
	212	213	214	215	216	217	218	219	220	221	222	223	224	225
	226	227	228	229	230	231	232	233	234	235	236	237	238	239
	240	241	242	243	244	245	246	247	248	249	250	251	252	253
	254	255	256	257										

X CORDINATE

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	2	3	4	5	6	7	9	10	11	12	13	14	16
	17	18	19	20	21	23	24	25	26	27	28	30	31	32
	33	34	35	36	38	39	40	41	42	43	44	44	45	46
	47	48	49	50	51	52	52	53	54	55	56	57	58	59
	60	61	61	62	63	64	65	66	67	68	69	70	71	72
	73	74	75	77	78	79	80	81	82	83	84	85	86	87
	89	90	91	92	93	94	95	96	98	99	100	102	103	104
	106	107	108	110	111	112	114	115	116	118	119	120	121	123
	0	0	0	0	0	0	124	123	122	121	119	118	117	116
	114	113	112	111	109	108	107	106	104	103	102	101	99	98
	97	96	94	93	92	91	89	88	87	86	85	84	83	82
	81	80	79	78	77	76	75	74	73	72	71	70	69	68
	67	66	65	64	63	62	61	60	59	58	57	56	54	53
	52	51	50	49	48	47	46	45	44	43	42	40	39	38
	37	36	35	34	33	31	30	29	28	27	26	25	24	22
	21	20	19	18	17	16	15	13	12	11	10	9	8	7
	6	5	3	2										

Y CORDINATE

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	32	32	32	32	32	32	32	32	33	33	33	33	33
	33	33	33	34	34	34	34	34	34	34	34	35	35	35
	35	35	35	35	35	36	36	36	37	38	39	39	40	41
	42	42	43	44	45	45	46	47	48	48	49	50	51	51
	52	53	54	54	55	56	57	57	58	58	57	57	56	56
	56	55	55	54	54	54	53	53	52	52	51	51	51	50
	50	49	49	49	48	48	47	47	48	48	48	48	48	49
	49	49	49	49	50	50	50	50	50	50	51	51	51	51
	0	0	0	0	0	0	43	43	42	42	41	41	40	40
	39	39	38	38	37	37	36	36	35	35	34	34	33	33
	33	34	34	35	35	36	37	37	38	38	39	39	40	40
	41	42	42	43	43	44	44	45	46	46	47	47	48	48
	49	50	50	51	51	51	52	52	52	53	53	53	54	54
	54	55	55	55	55	56	56	56	57	57	57	58	58	58
	59	59	59	60	60	60	61	61	61	62	62	62	63	63
	63	64	64	64										

ALTITUDES

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	1000	1000	1438	1438	1438	1438	1438	1813	1813	1813	1813	1813	2000	2000
	2000	2000	2000	2000	1925	1925	1925	1925	1563	2425	2425	2425	2425	2425
	2425	2425	2313	2313	2313	2313	2313	2313	2313	2588	2813	2813	2813	2813
	2813	2975	2975	2975	2188	2188	2188	2188	1700	1700	1700	1700	1700	1700
	1438	1438	1438	1838	1838	1275	1275	1275	1275	1275	1275	1168	1168	1168
	1168	1168	1150	1150	1238	1238	1238	1238	1155	1155	1155	1155	1158	1167
	1167	1167	1167	1267	1267	1267	1267	1325	1325	1325	1325	1325	1335	1335
	0	0	0	0	0	0	2289	2289	2254	2254	2258	2258	2258	2258
	2218	2218	2218	2218	2218	2168	2205	2205	2205	2205	2289	2289	2289	2289
	2289	2452	2452	2452	2452	2845	3713	3713	2713	2713	2025	2563	2563	2563
	2563	2563	2563	2938	2938	2938	2563	2563	2563	3500	3500	3500	3500	3500
	3500	3900	3900	3675	3675	3675	3675	2588	2588	2588	2588	2588	2313	2313
	2000	2000	2000	2000	1625	1625	1625	1625	1625	1625	1788	1788	1788	1788
	1788	1788	1788	1788	1788	1788	1875	1875	1875	1875	1875	1875	1750	1750
	1750	1750	1750	1375	1375	1375	2225	2225	2000	2000	2000	2000	2000	2000
	1375	1375	1375	1375										

COURSES

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	84	84	84	84	84	84	84	84	84	84	84	84	84
	84	84	84	84	84	84	84	84	84	84	84	84	84	84
	84	84	84	84	84	84	84	50	50	50	50	50	50	50
	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	50	50	50	50	50	50	50	50	50	111	111	111	111	111
	111	111	111	111	111	111	111	111	111	111	111	111	111	111
	111	111	111	111	111	111	111	82	82	82	82	82	82	82
	82	82	82	82	82	82	82	82	82	82	82	82	82	82
	0	0	0	0	0	0	249	249	249	249	249	249	249	249
	249	249	249	249	249	249	249	249	249	249	249	249	249	249
	249	249	249	249	249	249	249	249	299	299	299	299	299	299
	299	299	299	299	299	299	299	299	299	299	299	299	299	299
	299	299	299	299	299	299	299	299	299	299	299	299	299	299
	299	299	299	299	286	286	286	286	286	286	286	286	286	286
	286	286	286	286	286	286	286	286	286	286	286	286	286	286
	286	286	286	286	286	286	286	286	286	286	286	286	286	286
	286	286	286	286										

SPEED

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	420	420	420	420	420	420	420
	420	420	420	420	420	420	420	480	480	480	480	480	480	480
	480	480	480	480	480	480	480	480	480	480	480	480	480	480
	0	0	0	0	0	0	480	480	480	480	480	480	480	480
	0	420	420	420	420	420	420	420	420	420	420	420	420	420

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420	420	420	420	420	420	420	420	420	420	420	420	420	420
420	420	420	420	420	420	420	420	420	420	420	420	420	420
420	420	420	420	420	420	420	420	420	420	420	420	420	420
420	420	420	420	420	420	420	420	420	420	420	420	420	420
420	420	420	420	420	420	420	480	480	480	480	480	480	480
480	480	480	480	480	480	480	480	480	480	480	480	480	480
0	0	0	0	0	0	480	480	480	480	480	480	480	480

```
480 480 480 480 480 480 480 480 480 480 480 480 480 480
480 480 480 480 480 480 480 480 420 420 420 420 420 420
420 420 420 420 420 420 420 420 420 420 420 420 420 420
420 420 420 420 420 420 420 420 420 420 420 420 420 420
420 420 420 420 420 420 420 420 420 420 420 420 420 420
420 420 420 420 420 420 420 420 420 420 420 420 420 420
420 420 420 420 420 420 420 420 420 420 420 420 420 420
```

DATA OF THE PRIORITY MODEL

TIME STEPS

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
  20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
  38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
  56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
  74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91
  92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109
  110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
  128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
  146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
  164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
  182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
  200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
  218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
  236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
  254 255 256 257 258 259 260 261 262 263 264 265 266
```

TARGET 1

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1
```

TARGET 2

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 1 1 1 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
  2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1
  1 1 3 3 3 3 3 3 3 3 3 3 3 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 3 3 3 3 3 3 3 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
  3 3 3 3 0 0 0 0 0 0 0 0 0
```

TARGET 3

```
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
     1    1    1    1    1    1    1    1    1    3    3    3    1    1    1    1    1    1
     1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
     1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
     1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    0    0    0
     0    0    0    1    1    1    1    1    1    1    1    1    1    1    0    0    0    0
     0    0    1    1    1    1    1    1    1    1    1    1    1    3    3    3    3    3
     3    3    3    3    3    3    3    3    3    3    3    3    3    3    3    3    3    3
     3    3    1    1    1    1    1    1    1    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0
```

DATA OF TARGET DETECTION MODEL

1. SITE 1

```
         DETECTS1
1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19
    20   21   22   23   24   25   26   27   28   29   30   31   32   33   34   35   36   37
    38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53   54   55
    56   57   58   59   60   61   62   63   64   65   66   67   68   69   70   71   72   73
    74   75   76   77   78   79   80   81   82   83   84   85   86   87   88   89   90   91
    92   93   94   95   96   97   98   99  100  101  102  103  104  105  106  107  108  109
   110  111  112  113  114  115  116  117  118  119  120  121  122  123  124  125  126  127
   128  129  130  131  132  133  134  135  136  137  138  139  140  141  142  143  144  145
   146  147  148  149  150  151  152  153  154  155  156  157  158  159  160  161  162  163
   164  165  166  167  168  169  170  171  172  173  174  175  176  177  178  179  180  181
   182  183  184  185  186  187  188  189  190  191  192  193  194  195  196  197  198  199
   200  201  202  203  204  205  206  207  208  209  210  211  212  213  214  215  216  217
   218  219  220  221  222  223  224  225  226  227  228  229  230  231  232  233  234  235
   236  237  238  239  240  241  242  243  244  245  246  247  248  249  250  251  252  253
   254  255  256  257  258  259  260  261  262  263  264  265  266
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0    0    0    0    0    0    0    0    0    0    0    0    0
```

```
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   1   1   1   1   1   1   1
      1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
      1   1   1   1   1   1   0   0   0   0   1   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
```

2. SITE 2

```
      *DETECTS2
1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
     20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
     38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
     56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
     74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
     92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
    128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
    146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
    164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
    182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
    200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
    218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
    236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
    254 255 256 257 258 259 260 261 262 263 264 265 266
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1
      1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
      1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
      1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0
0 0 0 0 0 0 0 0 1 1 1 0 0 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0
0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
```

3. SITE 3

```
     DETECTS3
1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
    20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
    38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
    56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
    74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
    92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
   110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
   128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
   146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
   164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
   182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
   200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
   218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
   236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
   254 255 256 257 258 259 260 261 262 263 264 265 266
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  0 0 0 0 0 0 1 1 0 0 0 0 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0
  0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

0 0 0 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0

4. SITE 4

DETECTS4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91
92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
254 255 256 257 258 259 260 261 262 263 264 265 266
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0
0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 C 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```
  1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

DATA OF INTERCEPT MODEL

1. SITE 1

```
      INTERS1
1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
   20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
   38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
   56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
   74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
   92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
  110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
  128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
  146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
  164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
  182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
  200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
  218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
  236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
  254 255 256 257 258 259 260 261 262 263 264 265 266
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   6   6   5   5   5   5   4
   4   4   4   4   4   3   3   3   3   3   3   3   3   3   3   4   4   5
   5   5   6   6   6   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0  23  22  21  20  19  18  17
  16  15  14  13  13  11  10   9   9   9   8   8   8   8   8   8   8  10
  10  11  12  12  13   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0
```

2. SITE 2

```
     INTERS2
1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
  56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
 254 255 256 257 258 259 260 261 262 263 264 265 266
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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```

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  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
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5 6 6 6 6 7 8 8 8 9 9 0 0 0 0 0 0 0
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21 20 19 18 17 16 16 15 14 13 12 12 12 11 11 11 11 12
13 13 14 14 14 16 16 17 18 19 20 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   1   1   1   1   1   0   0   0   0   0   1   1   1   1   1
          1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
          1   1   1   1   1   1   1   1   1   1   1   0   0   0   0   0   0   0
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          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   1   1   1   1   1   1   1
          1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
          1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
          1   1   1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   9   9   9   8   8   0   0   0   0   0   8   7   7   7   7
          7   7   7   7   7   7   8   8   8   6   6   6   6   6   6   6   6   7
          7   7   7   7   7   7   8   8   8   9   9   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   9   9   9   9   8   8   8
          8   7   7   7   7   6   6   6   6   5   5   5   4   4   4   4   3   3
          3   3   3   2   2   2   2   2   2   2   2   2   3   3   4   4   5   5
          5   6   6   7   8   8   9   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
          0   0   0  34  33  32  32  31   0   0   0   0   0  26  26  26  25  24
         23  23  23  23  23  23  23  22  22  22  21  20  20  20  19  19  18  19
         19  19  19  19  19  19  19  20  21  21  22   0   0   0   0   0   0   0
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         32  30  30  28  27  26  25  24  22  21  19  18  17  16  15  13  13  12
         10  10   9   7   7   5   4   4   4   3   3   4   5   6   7   8   9  10
         11  12  13  15  16  17  18   0   0   0   0   0   0   0   0   0   0   0
          0   0   0   0   0   0   0   0   0   0   0   0   0
```

3. SITE 3

```
        INTERS3
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         20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
         38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
         56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
         74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
         92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
        110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
        128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
        146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
```

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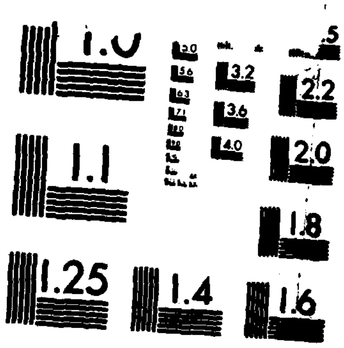
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
```

AD-A168 447   MODELING AIRCRAFT ATTRITION IN THE AIR DEFENSE   3/3
ENVIRONMENT(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA
G D PANAGAKOS MAR 86

UNCLASSIFIED   F/G 15/3   NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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9 9 8 8 8 8 8 8 8 9 9 9 9 9 9 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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32 31 31 30 29 29 28 28 27 27 26 26 27 26 27 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```
  29  28  27  25  24  23  21  20  20  18  17  16  15  14   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0
```

4. SITE 4

```
     .INTERS4
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    20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37
    38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
    56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73
    74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91
    92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
   110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
   128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145
   146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163
   164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181
   182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
   200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217
   218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235
   236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253
   254 255 256 257 258 259 260 261 262 263 264 265 266
0    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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     1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
     1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
     1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0   0   0
     0   0   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
     1   1   1   1   1   1   1   1   1   1   1   1   1   0   0   0   0   0
     0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
     1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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     0   0   0   0   0   0   0   0   0   0   0   0   0
0    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0  18  18  17  17  17  17  17  15  15  14  14  14  13
    13  13  13  13  12  12  12  12  11  11  11  10  10  10  10  10   9   9
     8   8   8   8   7   7   7   6   6   6   6   5   5   5   5   4   4   4
     4   4   4   3   3   3   3   3   3   3   3   4   4   5   5   0   0   0
     0   0   0   3   3   2   2   2   2   2   2   2   2   3   3   4   4   5
     6   6   7   8   8   9  10  10  11  11  12  13  14   0   0   0   0   0
     0  16  16  17  18  18  19  19  20  20  21  21  22  22  23  23  24  25
    25  25  26   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0
0    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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     0   0   0   0   0  69  69  67  66  66  65  65  64  62  61  60  58  57
    56  55  54  53  52  51  50  49  48  46  45  44  43  42  41  40  39  38
```

```
       [illegible]  13  12  10  10   9   8   8   8   8   8   9   9   9  11   0   0   0
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       11  12  13  14  15  17  18  19  20  21  24  25  26   0   0   0   0   0
        0  33  34  36  37  38  39  40  41  43  44  45  46  47  48  49  51  52
       53  54  55   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
        0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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        1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
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       19  19  18  18  18  18  18  17  17  17  17  16  17  17  16  16  16  16
       16  16  16  16  15  15  15  15  15  15  15  14  14  14  14  14  14  14
       14  14  13  13  13  13  13  13  12  12  11  11  11  11  11  11  11  10
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       11  11  12  12  12  12  13  13  13  12  12  13  13  13  13  13  14  14
       14  15  15  15  16  16  16  17  17  18  18  18  19  19  20  20  20  21
       21  22  22  23  23  24  24  25  25  26  26   0   0   0   0   0   0   0
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        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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       80  80  78  78  76  75  75  73  72  71  70  69  68  67  66  65  65  63
       63  62  61  61  59  58  57  57  56  56  55  54  53  52  52  51  51  50
       49  49  48  47  47  46  46  45  44  44  43  43  41  41  40  39  39  38
       38  37  37  36  36  35  35  34  33  33  33  33  33  33  32  33  32  32
       32  32  33  32  33  33  34  34  34  34  34  35  34  35  35  35  36  37
       37  38  38  38  39  39  40  41  42  42  43  43  44  45  46  47  48  49
       50  50  51  52  53  54  55  56  57  58  58   0   0   0   0   0   0   0
        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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        0   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
        1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
        1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0
```

```
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0  13  14  13   0   0
      0   0   0   0   0   0   0   0  10   9   9   0   0   9   9   9   9   9
      9   9   9   9   9   9   9   9   9   9   9  12  13  13  13  14  14  15
     16  16  17  17  18  18  19  20  20  21  21  22  22  23   0   0   0   0
      0   0  10  10  10   9   9   9   8   8   8   8   7   7   7   6   6   6
      5   5   5   5   4   4   4   4   4   3   3   3   3   2   3   3   4   4
      5   5   5   6   6   7   7   8   9   9   9  10  10  11  11  12  12   0
      0  14  14  15  15   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0  39  40  39   0   0
      0   0   0   0   0   0   0   0  36  34  34   0   0  32  31  31  30  30
     29  29  29  28  28  27  27  27  27  27  26  27  29  29  30  31  31  33
     34  34  35  36  38  38  40  41  41  43  44  45  46  47   0   0   0   0
      0   0  44  43  42  41  38  38  36  35  33  32  31  30  28  27  26  25
     23  22  20  20  17  17  16  14  13  12  11  10   8   7   8   8   9   9
     10  11  11  13  13  14  15  16  18  18  20  20  22  22  24  24  26   0
      0  29  30  31  32   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
      0   0   0   0   0   0   0   0   0   0   0   0   0
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